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Using the environment
3 Tackling problems
Part 2

Macdonald Educational

A Unit for Teachers

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Using the environment 3 Tackling problems Part 2

A Unit for teachers

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The Science 5/13 Project

'Science 5/13' is a project sponsored jointly by the Schools Council, the Nuffield Foundation and the Scottish Education Department, and based at the University of Bristol School of Education. It aims at helping teachers to help children between the ages of five and thirteen years to learn science through first-hand experience using a variety of methods.

The Project produces books that comprise Units dealing with subject areas in which children are likely to conduct investigations. Some of these Units are supported by books of background information. The Units are linked by objectives that the Project team hopes children will attain through their work. The aims of the Project are explained in a general guide for teachers called *With objectives in mind,* which contains the Project's guide to Objectives for children learning science, reprinted at the back of each Unit.

Foreword

Margaret Collis has been a valued friend of the Science 5/13 Project since it began. It is entirely appropriate, therefore, that having written *Using the environment,* she should, with characteristic generosity, have made it part of the Project's materials.

For years before the Project even began she, I and others in the Project team had been working together on teachers' courses and on committees of various kinds, exploring child-centred ways of working in science and helping to introduce them into schools. Margaret Collis still works tirelessly with teachers of varied experience, and in the generous atmosphere she always creates, they respond with enthusiasm and conviction. She has become aware of their doubts and uncertainties, and having accumulated a great store of first-hand knowledge about what they really want to know, she offers them the advice they need and through it the confidence they seek.

Both knowledge and advice are now recorded in a book for teachers to keep by them and to consult year by year. It took many years to write, and it will be many more in active service.

L. F. Ennever
University of Bristol
1974

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Acknowledgements

The Project is deeply grateful to its many friends: to the local education authorities who have helped us work in their areas, to those of their staff who, acting as area representatives, have borne the heavy brunt of administering our trials, and to the teachers, heads and wardens who have been generous without stint in working with their children on our materials. The books we have written drew substance from the work they did for us, and it was through their critical appraisal that our materials reached their present form. For guidance, we had our sponsors, our Consultative Committee and, for support, in all our working, the University of Bristol. To all of them we acknowledge our many debts: their help has been invaluable.

It is a pleasure to acknowledge some further help of special value. Mr L. C. Comber, chairman of the Consultative Committee for the Science 5/13 Project and formerly HM Staff Inspector for Rural Studies, read the first draft of *Using the environment*. His comments and suggestions have been of the greatest possible assistance in the work that followed.

Some of the apparatus photographed in Volume 3 has been constructed by Mr W. A. J. Edwards and Mr D. Postill, Kent Education Committee Inspectors. They have also checked sections in this book where there is emphasis on mathematical ideas and the use of electricity.

Metrication

This has given us a great deal to think about. We have been given much good advice by well-informed friends, and we have consulted many reports by learned bodies. Following the advice and the reports whenever possible we have expressed quantities in metric units with Imperial units afterwards in square brackets if it seemed useful to state them so.

There are, however, some cases to which the recommendations are difficult to apply. For instance we have difficulty with units such as miles per hour (which has statutory force in this country) and with Imperial units that are still in current use for common commodities and, as far as we know, liable to remain so for some time. In these cases we have tried to use our common sense and, in order to make statements that are both accurate and helpful to teachers, we have quoted Imperial measures followed by the appropriate metric equivalents in square brackets if it seemed sensible to give them.

Where we have quoted statements made by children, or given illustrations that are children's work, we have left unaltered the units in which the children worked—in any case some of these units were arbitrary.

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Introduction

This is a book about field studies. It deals with investigations and problems children can discover through their natural interest in their outdoor surroundings. Such first-hand experience, gained from the environment, is the basis of learning, provoking thought, giving children many ideas to share through speech and writing and sending them to books and other secondary sources of information to add to their own findings.

In the countryside there is so much more material of educational value than one book can cover that here there must be selection. We concern ourselves with things that have always interested scientists—natural phenomena that can be investigated through the human senses.

No rigid course with the same material for all is offered; that would fail to satisfy children's individual needs. When children work naturally they respond to the same starting points in different ways and soon become interested in different aspects of a common study. Later, as their development continues, they acquire the ability to make general statements about their experience or, as we usually say, 'form concepts', but, here again, it is through varied experience that each child's understanding of ideas is consolidated and deepened.

Piaget, and others, have shown that children pass through the same stages of intellectual development in acquiring the power of conceptual thought, but there is nothing sudden about this maturing, it is something children come to at their own rate with frequent returns to earlier ways of thinking and working when new situations have to be faced. This means that we shall find children, even of the same age, at different stages in the way they learn from their surroundings, so teachers must be prepared to vary their influence correspondingly. For these reasons the material in this book is arranged in an order that can be related to children's changing needs as their experience of outdoor investigation increases.

Volume 1 is concerned with the earliest exploration beyond the classroom when children need experience that can sharpen their sensory perception and help them to think about the numerical and spatial aspects of their surroundings.

Usually this would apply to infants but older children, coming to field studies for the first time, will need some practice in early stages of the work before they become ready to deal with studies appropriate for more experienced investigators.

Volume 2 contains many questions and suggestions designed to help children work actively and purposefully on studies in depth. They become ready to do this when they find something of particular interest on which they wish to focus attention.

Volume 3 could serve as an impetus to children's investigation of some major biological ideas and relationships through the design of controlled experiments. They should be able to deal with the reasoning this involves as their capacity for abstract thought develops.

Volume 4 is relevant to fieldwork at all times. It deals with ways and means of providing the facilities, equipment and raw materials children need for all stages of their outdoor investigations and resulting activities on their return to study areas in school.

A book concerned with the countryside should create awareness of the many ways in which living things and environmental conditions affect each other, so suggestions for studying these relationships and the consequences of disturbing them have been included. Every future citizen requires this knowledge as a basis for responsible attitudes towards the use of land and natural resources (ie *conservation*) in view of the ever-increasing demands a rising world population and desire for better standards of living will continue to make on the world's finite stores of materials.

Although this book is about children it is not for them; it is a book for teachers and it could not have been written without their help. Many teachers, and in particular some in Derbyshire and Kent, have contributed directly or indirectly to its contents. They have done so by encouraging children to pursue scientific interests, share common experiences and record what seems significant to them. They have collected questions children have asked, described models they have designed and noted suggestions and problems that have absorbed their attention. In this way a large collection of ideas has emerged from children's purposeful activity, guided carefully by thoughtful teachers. This is now available as a source of inspiration from which other teachers can select when children they know, show by their questions and behaviour, that they are near the end of their own ideas and resources and need contact with the greater experience of an interested adult.

We suggest that before reading this second part of *Tackling problems* teachers should read the first chapter of Part 1 since the general principles discussed there are applicable to the whole of Volume 3.

The boys in the photograph are using a ventimeter to obtain a direct reading of the speed of the wind. Many yachtsmen observe this weather condition in the same way

1 Problems concerning the distribution of living things

Volume 2 of *Using the environment* deals with experiences through which children can become aware of the uneven way in which plants and animals are distributed. (Volume 2 Part 1, pages 9–19).

This unevenness is a very fruitful source of investigations, since it gives children so much to compare and so many chances of becoming curious about possible reasons for living things being where they are.

When children try to discover how many plants or animals there may be in any one place they also need encouragement to look out for environmental conditions that may be affecting the living things they wish to study. Here is a reminder of some ways in which this encouragement could have been given at an earlier stage:

1. Extending the range of sites to be explored, from school grounds to the neighbourhood, and then to different places such as areas of chalk grassland, woodland, sandy and rocky seashore, meadowland and heath.

2. Encouraging individual children to search their neighbourhood for places where plants of their own choice flourish and to notice other situations where these never seem to appear. In what ways are two such habitats different? Would such differences be likely to affect living things?

3. Collecting records of living things discovered in named situations, such as rapidly moving water, shady places or trampled ground.

4. Making a collection of widely distributed living things; that is, those found in almost every place. Are the same species of these plants when found in different places the same size when full grown?

Investigating different aquatic habitats

5. If plots in the school grounds have been used as outdoor laboratories, and some studies of life histories of animals have been made, children should be aware that the needs of living things for moisture, food, space, etc, can show much variation.

Twelve or thirteen-year-old children who have gathered this type of past experience might now be encouraged to extend their investigations by searching for further evidence of relationships between varying quantities of self-chosen living things and certain environmental conditions.

Since such investigations can become complex and difficult, we might begin by considering what could be involved in a hypothetical example, and then decide on what we could reasonably expect children of this age to attempt.

Here we have a view of a lake in a nature reserve set up by the Central Electricity Generating Board in Canterbury.

The wooden platform and some bridges linking islands give safe access to water varying in depth.

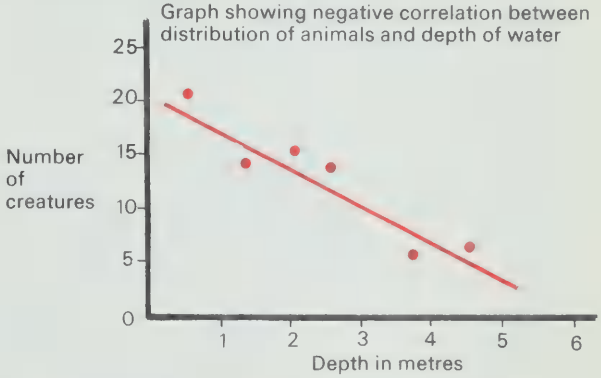
A session on the viewing platform

Children working at selected stations can dip for specimens of a commonly occurring creature, mayfly larvae for example, count the number obtained from the same number of catches, then after returning the creatures to the lake, measure the depth of water where each collection was taken.

Using jam jars for taking samples from the lake

If uneven numbers of creatures obtained through such a combined operation show similar or opposite trends to the different measurements of depths, we can say that there is some association (or, in scientific terms, positive or negative correlation) between the two sets of data.

Graph showing negative correlation between distribution of animals and depth of water



Such a result could be accepted as evidence of a relationship.

It is at this point that caution is necessary. Any children obtaining the results described would have grounds for thinking that the suggestion that certain depths of water provide the most suitable conditions for mayfly larvae is on the right track. But they would not be justified in claiming the variation in this one environmental condition as the cause of any uneven distribution of the creatures.

Teachers can prevent such false claims if, at this stage, they encourage the children to think critically about the situation, for example :

Some of the collecting areas are shaded by trees whilst others are exposed to sunlight. This should cause light reaching these waters to vary in intensity. Could the larvae be sensitive to this ?

Shading and differences in depth may cause differences in the temperature of the water. Perhaps mayfly larvae congregate more readily in places where the temperature is within a certain range.

Even if a more ambitious investigation in which intensity of light, temperature and depth of water measured in turn,

should provide evidence that each condition is likely to be exerting some influence on the uneven distribution of the larvae, each condition is not likely to be doing so to the same extent.

It is not surprising that adult scientists able to make use of appropriate mathematical techniques find this kind of problem very difficult and the search for solutions a continuing process.

What is quite evident is that the children we are considering should not be encouraged to base conclusions about the cause and effect of environmental conditions on the results they are able to obtain. This does not mean that they should avoid searching for relationships.

When they wonder why there is more of a certain plant or animal in one place than in another, they should certainly be encouraged to suggest reasons and to search for evidence supporting their ideas.

Such experience can be of great value in helping them to realise that a number of environmental factors are likely to be affecting each living thing at the same time, influencing where they are, what they are like, and when and how they change.

Also, through tackling such problems they will find good reasons for wanting to count and estimate numbers of plants and animals and for measuring environmental conditions. The futility of using these quantitative techniques without good reasons has already been emphasised. (See Volume 3 Part 1, page 8.)

In this and Chapter 3 methods of counting and estimating numbers of living things are considered, and constant reference is made to situations in which these methods might be used. This is followed by three chapters containing information about ways of measuring some environmental conditions resulting from climate, the nature of the land and water, and the influence of living things. From all these sources suitable ways of obtaining the two sets of data required for comparison can be selected each time a problem needs to be tackled.

Investigating distribution by counting

It is easier for children to begin this quantitative work with plants and sedentary animals as these usually remain in the same places.

The number of mobile animals found in a place at any one time may have little significance, for their movement will alter the picture. Therefore repeated investigations are necessary when trying to find out something about the pattern of any particular animal's behaviour or distribution.

For beginners the problem of naming many different things can be avoided by tackling studies involving the distribution of *one type* of plant or animal. Are there more here than there ? Counting need not be a tedious job if the work is shared by many children. (See pages 11 and 12.)

Here are some straightforward investigations that might be attempted by groups of children aged between eleven and twelve.

Problems involving comparisons of numbers of the same species of a plant or animal on two areas of similar size

Questions that could serve as starting points	Suitable plants or animals to count	Time of year for investigation
Where are the most specimens ?		
1. On the north or south side of the hedgerow ?	White dead nettle (*Lamium album*) Hedge parsley (*Caucalis anthriscus*) Hedge woundwort (*Stachys sylvatica*) Figwort (*Scrophularia nodosa*)	April to October May, June May to July May to September
2. On the north or south side of the wall ?	Mosses and lichens Pennywort (*Cotyledon umbilicus*)	Throughout year May to July
3. Beneath the hedge or on the grass verge near the road ?	Lesser celandine (*Ranunculus ficaria*) Cuckoo pint (*Arum maculatum*) Common horsetail (*Equisetum arvense*)	March, April April, May June, July
4. On the ridges or grooves of shingle beaches ?	Horned poppy (*Glaucium flavum*) Common bugle (*Ajuga reptans*) Maritime variety of woody nightshade (*Solanum dulcamara*)	June to September April to July June to September
5. On the shaded or open part of a woodland floor ?	Self-heal (*Prunella vulgaris*) Common avens (*Geum urbanum*) Wood anemone (*Anemone nemorosa*) Dog's mercury (*Mercurialis perennis*)	May to October July, August March, April April to September
6. On a piece of heathland recently affected by fire or an unburned area ?	Gorse (*Ulex europaeus*) seedlings	Throughout year
7. On the east or west side of the breakwater ?	Acorn barnacles (not necessary to distinguish different species)	Throughout year
8. On the windward or leeward side of the boulder ?	Common limpet (*Patella vulgata*)	Throughout year
9. On the hedge at a height of 0 to 1·5 m or from 1·5 to 3·0 m ?	Spider webs	September

Problems involving changes in numbers of plants or animals in the same area

These are long-term studies, only possible when a site can be observed regularly and frequently. Such investigations are useful for providing information about colonisation by plants or the habits of animals.

Questions that could serve as starting points	Suitable plants or animals to count	Time of year for investigation
1. How many specimens can you find on the flower border by the lawn on each Monday morning ?	Groundsel (*Senecio vulgaris*) Shepherd's purse (*Capsella bursapastoris*) Red dead nettle (*Lamium purpureum*) Ground elder (*Aegopodium podagraria*) Pale willow herb (*Epilobium poseum*)	Throughout year May to October May to September
2. How many seagulls on the school field at 9 am each day ?	Seagulls (any species)	Throughout year
3. How many ducks on the park lake every day at noon ?	Mallard ducks (male) Mallard ducks (female) Ducks (any species)	Throughout year
4. How many marked snails on the waste ground by the garden wall ?	Garden snails (*Helix aspersa*)	Summer
5. When can you find most slugs near the hedgerow, on dry or wet days ?	Garden slug (*Arion hortensis*) Large black slug (*A. ater*)	Summer

Problems involving comparisons of numbers of two species of the same family or two varieties of the same species that can be found on the same site

Is their distribution according to any pattern or are they mixed haphazardly ?

This work is suitable for children who have become sufficiently experienced to be able to distinguish between two closely related species of plants or animals.

Questions that could serve as starting points	Suitable plants or animals to count	Time of year for investigation
1. Which plants are more frequent in this area, ——— or ——— ?	Bulbous and meadow buttercups (*Ranunculus bulbosus* and *R. acris*) Red and white campions (*Silene dioica* and *S. alba*) Pin and thrum-eyed primroses (*Primula vulgaris*)	May May to July May
2. Are there more pink or more white wild roses on this length of hedgerow ?	(Varieties of these plants often difficult for children of limited experience to distinguish so better to use colour at this stage)	May, June
3. Which periwinkles are present in the greatest number on the part of this seashore covered by *Fucus* spp. ?	Flat periwinkle (*Littorina littoralis*) Common or edible periwinkle (*L. littorea*)	Throughout year
4. Which type of wood louse is most common beneath this row of stones ?	Garden slater (*Oniscus asellus*) Pill wood louse (*Armadillidium vulgare*)	Throughout year

Organisation for the collection of data relevant to the problem

When children are new to this work it is advisable for them all to work as a class or in a group for a time, for they will all need the same kind of guidance from the teacher.

It is also an advantage if the first investigations can be carried out in the school grounds, on a site in the immediate neighbourhood or on land adjoining a field centre. Then, when the initial reconnaissance to find a suitable problem has been carried out, everybody can easily return to an indoor base to plan the next part of the campaign, share out the jobs, prepare or gather together equipment, and learn and practise techniques. These preparations will enable children to make their observations swiftly and efficiently when they return to the outdoor site.

Later, when they are more familiar with methods of working, pairs and small groups of children can undertake different investigations at their own rate.

The following tasks are those likely to be shared by members of a class or group :

1. Defining boundaries of the study area in which counts of plants or animals are to be made.

2. Dividing this area into smaller plots.

3. Numbering plots.

4. Counting specimens on each plot (by pairs of children as a double check).

5. Giving results of counts to a recorder for totalling on a chart or model with its parts numbered to correspond to the subdivisions of the study area.

When the numbers of the same species in two areas have to be compared, as on both sides of a hedge, the procedure just described must be carried out in each place. Two groups of children can be involved.

When a plan of campaign is well organised many children can share the work. However, if fieldwork can only be done by a whole class at a considerable distance from a base the teacher may prefer to train a few children at a time to deal with quantitative work while other members of the class continue with more familiar investigations. In this kind of situation additional help from students from a college of education can prove invaluable.

Equipment for marking out study areas

Plastic marking lines of various lengths with metal meat skewers attached to their ends are required. The lines should be marked at metre intervals with waterproof ink.

A skewer may be attached to a plastic line by bending the end of the line round the handle of the skewer, and then whipping the loop with a length of string.

Rope or string may be used instead of plastic line but it is less conspicuous when pegged over the ground and also it cannot be dried so easily after use in damp places.

Marking lines should be rolled round lengths of broomstick for storage and transport to the outdoor working area.

Seed labels for numbering the plots, as well as a few rulers, tape measures and chalk, will also be needed.

Suggestions for subdividing study areas

The way in which areas should be subdivided and the number and length of marking lines required will depend on the nature of the investigation and size of the area. Rough estimates of length of boundaries can be made by pacing during the first visit to the site.

Investigations involving the use of very large areas and work on ground covered by dense undergrowth should be avoided.

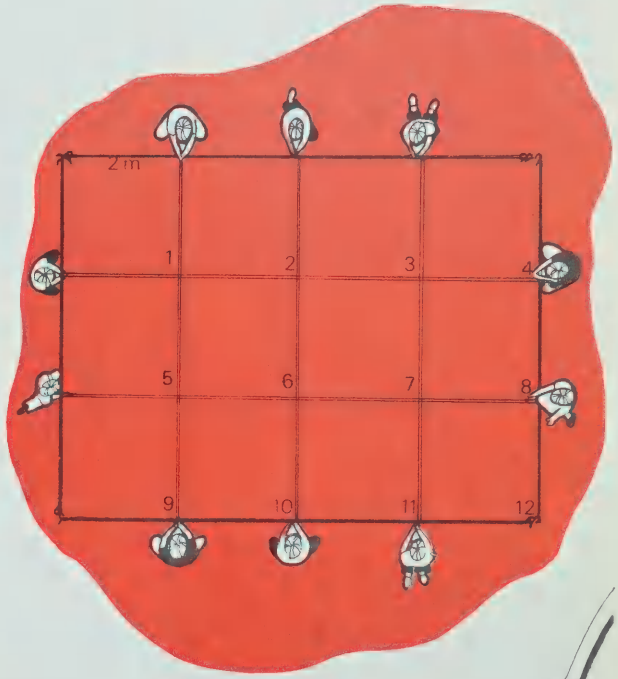
When a good way of subdividing the area has been devised children should be encouraged to practise setting out their marking lines on the school field or playground, and so prepare themselves for carrying out their various tasks without delay on return to the study area.

Areas of woodland floor, heath, seashore

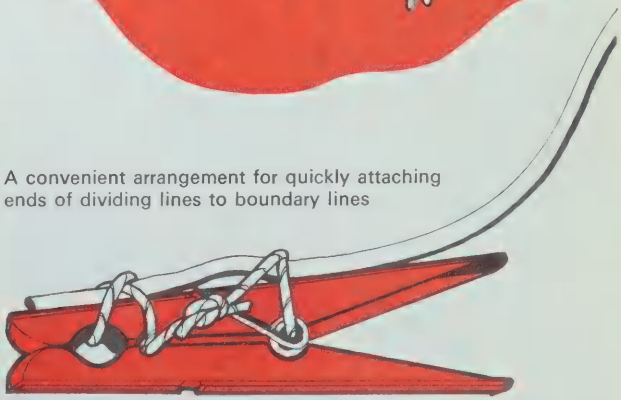
Peg down the boundary lines of the largest rectangle the site can accommodate. Small irregular pieces of ground beyond these boundaries can be ignored or examined separately.

Peg down dividing lines to join selected points on boundaries.

Here we have an arrangement that will allow twelve pairs of children a working area of 4 m^2 each. Each pair should place a numbered peg in the corner of their square before making their counts of the plant under investigation.

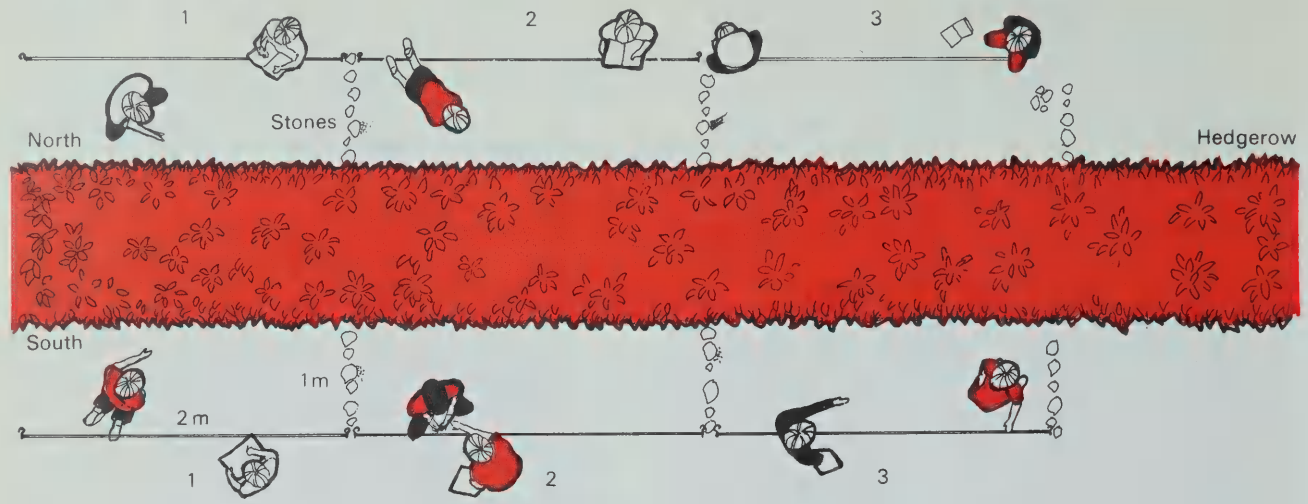


A convenient arrangement for quickly attaching ends of dividing lines to boundary lines



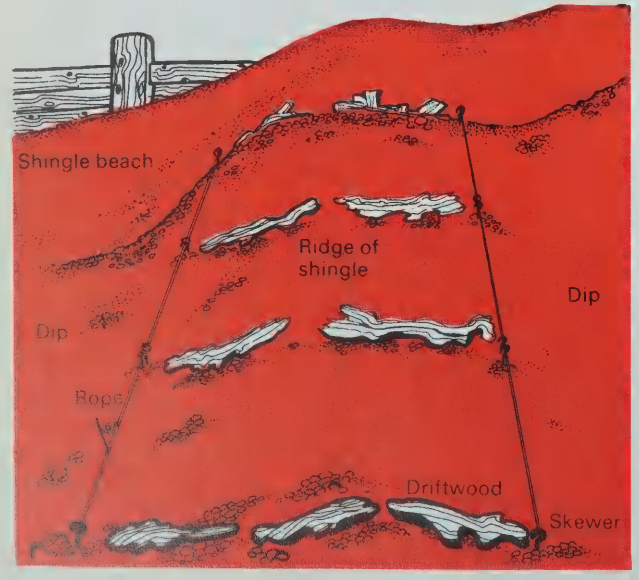
Vertical areas on walls or breakwaters can be subdivided in this way by chalk lines which should be erased when the survey has been completed.

Linear sites



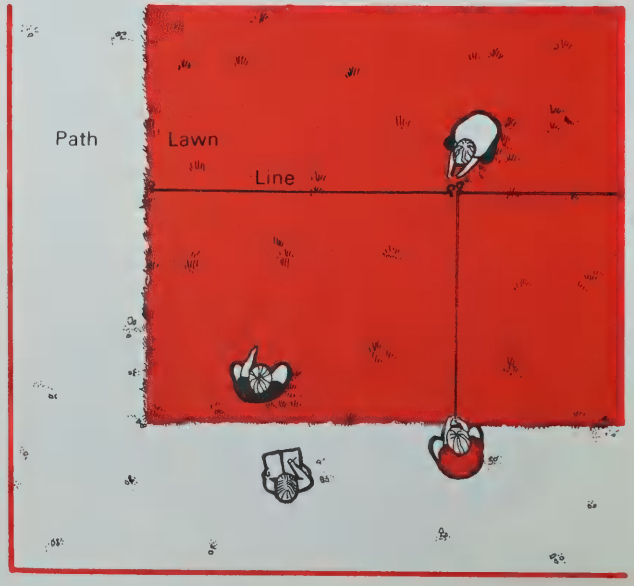
Children will survey linear areas when they try to compare the distribution of certain plants in places like ground on opposite sides of a hedge, grassy borders of a lane, parallel ridges and dips caused by wave action on a shingle beach or different strips on a lawn.

Ridge of shingle subdivided for study with ropes and driftwood



Pairs of children can define their own working areas very rapidly by pegging 2-m lines end to end at a convenient distance (eg 1 m) from say a hedgerow. Overlap in counting can be prevented by temporary boundaries of stones or twigs.

Marking plots on edge of lawn for comparison with strip in centre



Recording observations

Totalling counts

When they have finished counting, the pairs of children dealing with different sub-divisions of a site should give their results to a recorder to enter on a chart prepared before leaving school.

Here is an example showing how gorse seedlings discovered on an area of heathland sub-divided as shown on page 11 might be recorded and totalled.

Date..... Gorse seedlings on recently burned heathland				Totals
8	1	2	0	11
0	3	0	0	3
0	1	7	1	9
Grand total				23

Another sheet will be required for recording the counts made on a similarly sized site unaffected by fire.

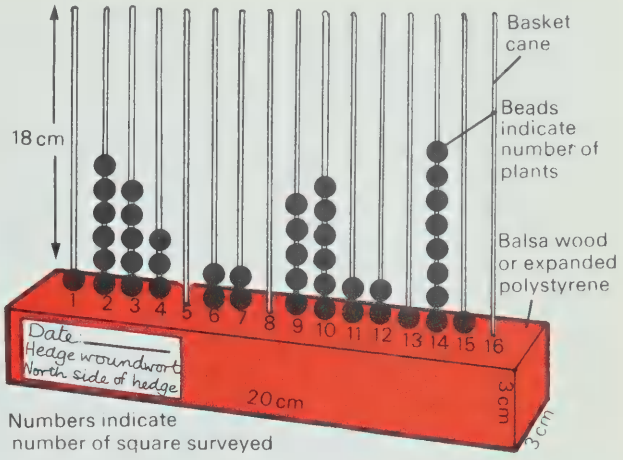
Date..... Hedge woundwort	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Totals
North side of hedge	1	6	5	3	–	–	2	6	5	–	3	3	1	7	3	45
South side of hedge	1	1	–	–	–	2	1	–	–	–	3	2	–	–	–	10

This is the kind of chart which the pairs of children, shown working near the hedgerow on page 12, could be expected to produce as a result of investigating the distribution of hedge woundwort during May.

Pictorial representation

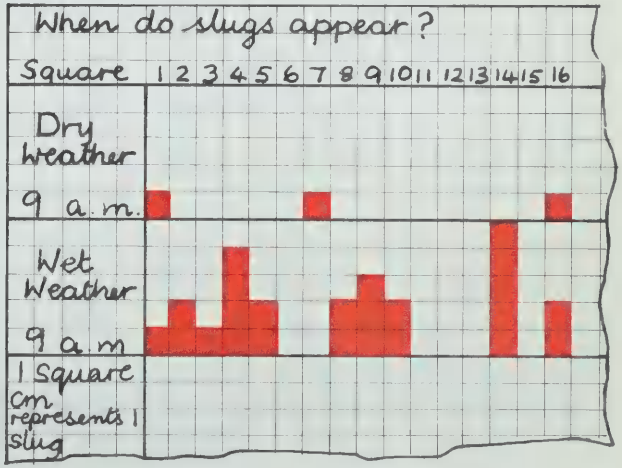
Any pattern that may exist in the distribution of the plants or animals under consideration can be most effectively revealed by visual methods of recording. They thus have particular value as a basis for discussion.

Graphs



Numbers indicate number of square surveyed

Each pair of children is responsible for the column representing plants in the small area they examined.



Examine grass near the hedgerow bordering the school field at 9 am each day and record the numbers of slugs seen by filling in squares on appropriate parts of the class graph.

For examples of graphical records based on observations of birds, see Volume 2 Part 2, pages 86–87.

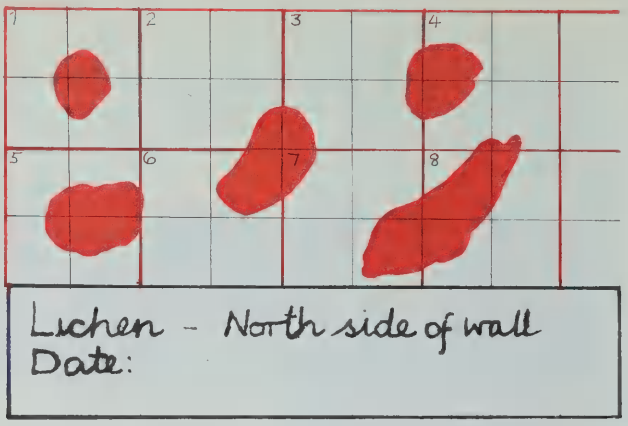
Models and charts

These may be used for showing both the quantities and the positions of plants or animals that were observed.

Out of doors the position of each plant or animal under observation in each numbered square of a sub-divided study area is recorded by the children responsible. This can be done by fixing map pins to a polystyrene square or by placing signs on a square of graph paper. (A polystyrene tile 30 · 30 cm provides four squares.)

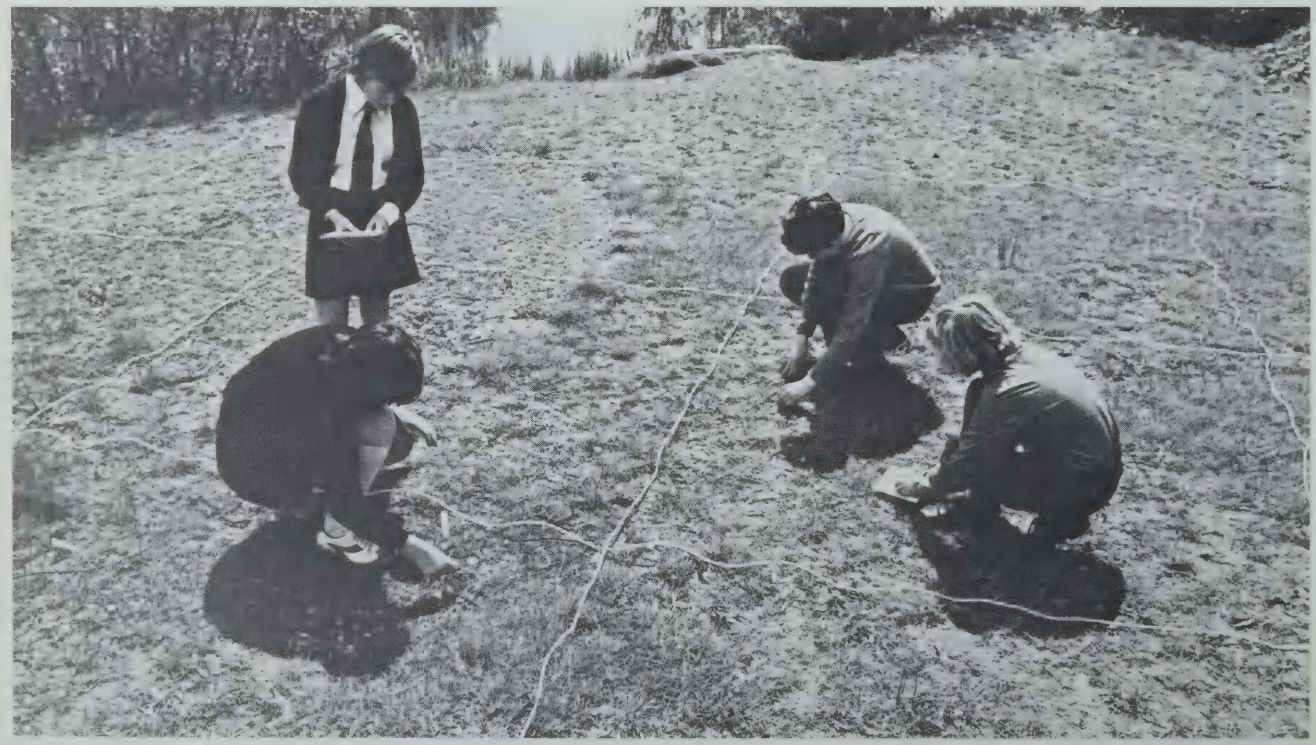
On return to the classroom squares can be stapled in the correct order to a wall board or flat piece of chip board.

Plants that spread to form patches as they increase in number can be recorded by mapping on squared paper, for example, lichen on a wall.



Children's maps of the squares studied can be mounted in order on to a backing sheet. A series of charts will show changes in growth.

Recording white clover flowers on different plots in the study area



Transferring results of counting white clover flowers to a model of the outdoor study area

Investigations involving a greater variety of living things

As children's skill in identifying their finds grows, they can be encouraged to apply the techniques they have learned to investigations involving a number of different living things. The extent of this variety should be related to the experience and ability of the children.

Here are two examples of the type of studies children might tackle as they become more confident and their interest in quantitative work increases.

A study of waste ground

While studying an area children might make use of a chart like this one compiled by Dr J. Brierley, HMI, which refers to waste ground. This will help them combine qualitative observations about a number of common plants with estimations of their frequency on different parts of the site.

Similar charts could be constructed for the same place at different seasons or for places where environmental conditions are different. Comparisons of these charts might reveal interesting information about plants that are common everywhere and plants that appear to be limited to certain places.

Site..... Date.....	State of plant		Dura-tion	Dis-persal	Stor-age organ	Habit	Frequency of plant in different situations		
	In flower	In fruit					General surface	New paths	Dumps
Herbs									
Chickweed									
Chickweed mouse-ear									
Coltsfoot									
Dock									
Dandelion	—	✓	P	H/Fr	T	Ro	F	O	R
Groundsel									
Hawkweed									
Mayweed									
Mugwort									
Stinging nettle									
Plantain (hoary)									
Plantain (ribwort)									
Grasses									
Cocksfoot									
Soft grass									
Couch									
Trees									
Birch									
Elder									
Sycamore									

Code

Duration
An Annual
B Biennial
P Perennial

Dispersal
W Winged fruit seeds
H Hairy fruit seeds
K Hooked fruit seeds
S Small fruit seeds
Sh Shaker
V Vegetative

Habit
Ro Rosette
E Erect
C Creeper
M Climber
Ev Evergreen
L Low herb

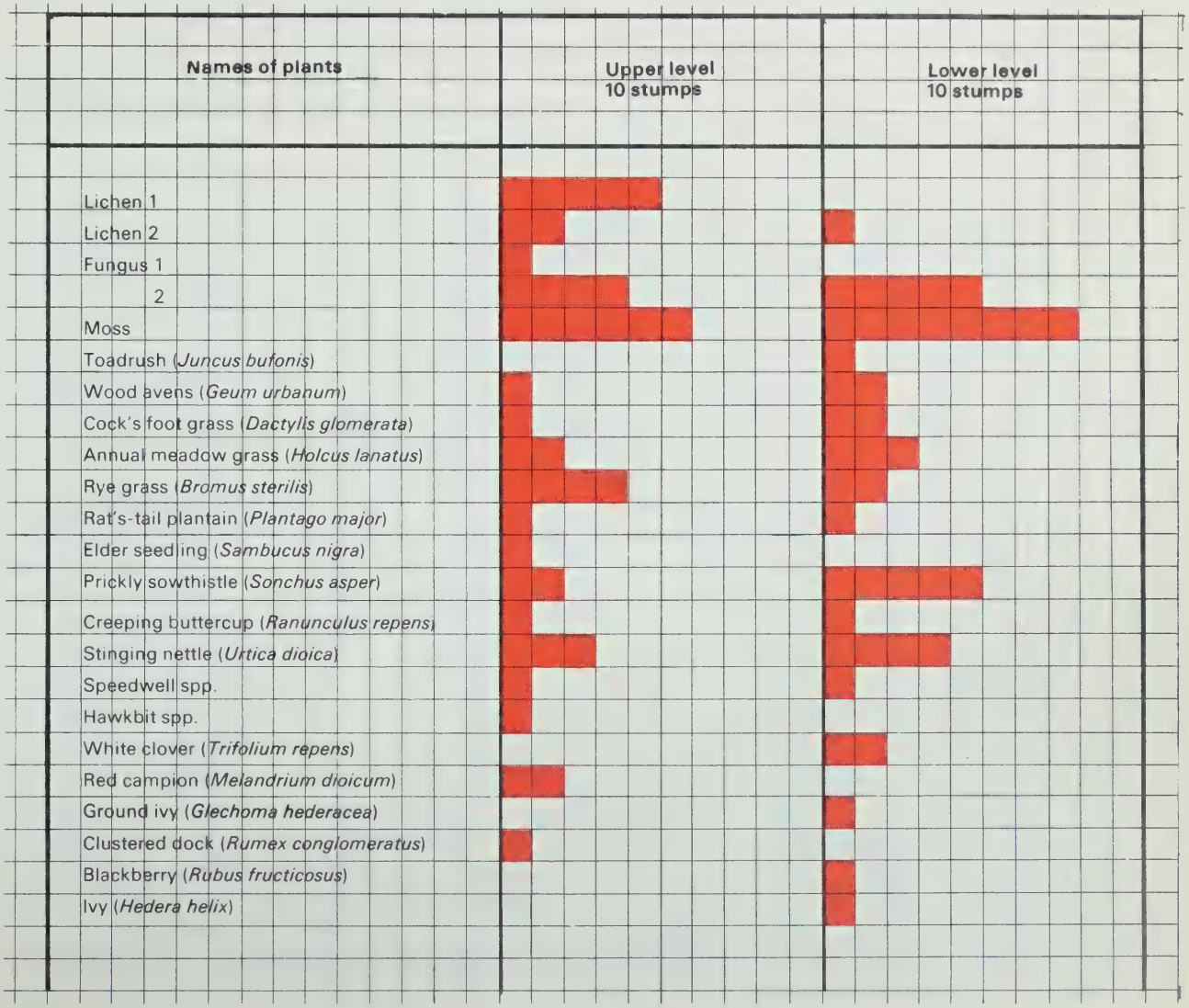
Frequency
A Abundant
F Frequent
O Occasional
R Less than 5 plants seen

Storage organ
T Tap root
Rh Rhizome
Fi Fibrous

A study of plant growth on and around tree stumps

During the summer of 1960 some trees covering a south-eastern facing slope in the grounds of a boys' secondary school were cut down, but all their stumps were left in position. The grass on this slope was cut from time to time, but it was not possible to get the mowing machine close to the stumps. Two years later in July a group of boys aged twelve plus compared the growth on and around ten stumps selected from the top and ten from the bottom of the slope.

Here is a quantitative record they made of their investigations.



Further suggestions for investigations

1. A comparison of the plants and animals inhabiting two pools of similar area and depth at different levels on a rocky seashore or in shaded and sunny positions.

2. A comparison of the wild flowers in bloom in July on two similar-sized grass strips bordering opposite sides of a country lane.

3. The variety of weeds found between cracks in footpaths of urban areas. Compare similar lengths in different streets.

Does the number and variety of plants found vary according to :

The material of which the path is made ?
Whether a path is separated from the road by a grass border ?
Whether houses in the street have front gardens ?
Whether the inhabitants of the street own or rent their houses ?
Whether the street is a cul-de-sac or a through road ?

4. Bare patches can often be found on the grass borders of country roads when heaps of gravel for road repairs have been removed. Records of the way such patches are recolonised can be built up if the same patch is mapped regularly.

Treating an experimental plot with liquid fertiliser. The control will be left unfertilised

2 What happens when there are too many living things to count?

There will come a time when children will want to know more about the quantities of things in a particular place, but will find that there are too many to count. Sometimes it is easy to decide that the exact information counting gives is not worth the labour and time involved and that a rough estimation will serve the purpose equally well.

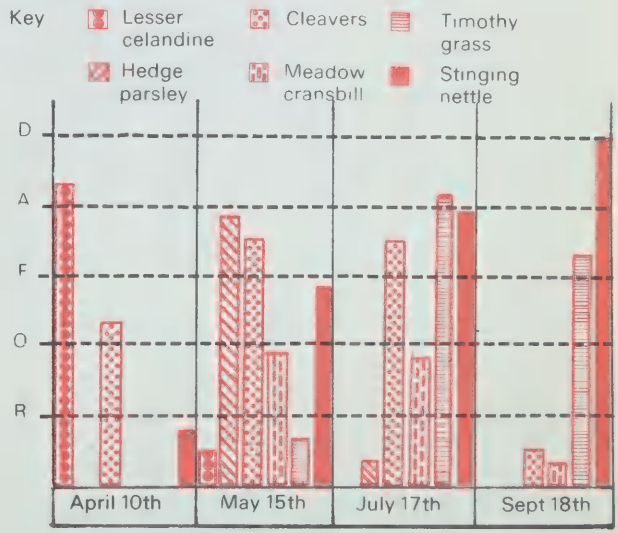
Children will need a scale against which they can consider their estimations. This will provide the teacher with a good opportunity to introduce the ecological terms in general use for indicating quantities.

Before an outdoor expedition children should reach agreement, through discussion, about the approximate quantities to be represented by each symbol. Then their individual observations will be comparable.

Here is an example.

Ecological term	Symbol	Relationships children might agree to adopt
Dominant	D	Plant covering whole site
Abundant	A	Sufficient plants present to cover about three-quarters of site
Frequent	F	Sufficient plants present to cover about half the site
Occasional	O	Plants present will not cover more than a quarter of the site
Rare	R	Less than five on the site

The following record was made with the help of a scale by a group of twelve-year-old members of a school natural history society as part of their study of the growth of six plants on a piece of waste ground. On four occasions during the spring and summer they made estimations of the quantities of these plants in flower.



These rough estimations are quite sufficient to show how different plants are available for pollination at different times throughout the flowering season.

The habit of making estimations is well worth developing, not only as a time-saver, but because it is a good way of giving children some initial experience of the concept of probability. If, for example, they decide to describe the quantity of buttercups in a meadow as Abundant (A), they are making a judgement by appearances of the probable quantity there.

Sampling

When children need more information than they can obtain by looking and estimating it is time to help them to understand and use the technique of sampling, a method which uses the concept of probability.

In sampling, parts chosen at random from the whole are carefully investigated and from this knowledge a prediction on the probable state of the whole is made.

Here are some everyday situations in which the state of the whole is estimated after a test of a small amount. They can serve as examples to help children think about the concept of sampling.

Testing the baby's bath water with an elbow.
Feeling the water of the swimming pool with one toe.
Pushing in and withdrawing a knife to see if a fruit cake is cooked.
Tasting a little juice from a saucepan of stewed fruit for sweetness.
Testing small quantities of drinking water to discover whether the supply is satisfactory.
Advertising goods by means of commercial samples.
Gallup polls.

Sometimes situations will arise that stimulate children to devise their own ways of sampling.

Mowing a field

A few years ago some children of ten and eleven from a village school were returning from an outdoor ramble when they saw the gang mower from the County Estates Department moving away after mowing their school field. From conversation about its work the question arose—what about weeds on our field, does the mower get rid of them when it cuts the grass ? They realised that it would be impossible to look closely at every piece of such a large field, and yet one particular part might not be like all the rest. Some way must be suggested of getting their observations distributed as widely as possible over all parts of the area.

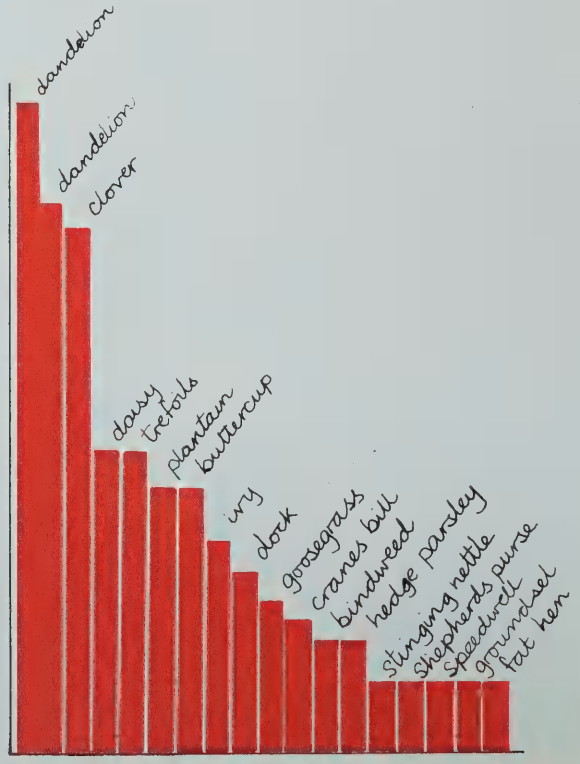
What happened when the children made use of a method devised in the course of class discussion is best told by looking at the children's own work.

Being Explorers 23rd June

For the first half of the afternoon we were on the field. We were to find as many different plants as we could in the grass. We did not count everything in the field. We made a long line across the field and were each given a piece of string a yard long. Then we each walked in a straight line down to the bottom of the field and at every yard we stopped and picked the plant there if it was not grass. This is what we found when we added all our finds together.

Daisies 19, Goose grass 6, Dock 7, Clover 33, Buttercup 17, Fat hen 1, Dandelion 74, Bindweed 3, Ivy 11, Speedwell 1, Stinging nettle 1, Cranesbill 4, Plantain 17, Trefoils 19.

We made a picture called a graph by colouring one square for each plant.



Now we have made the graph this is what it tells us.

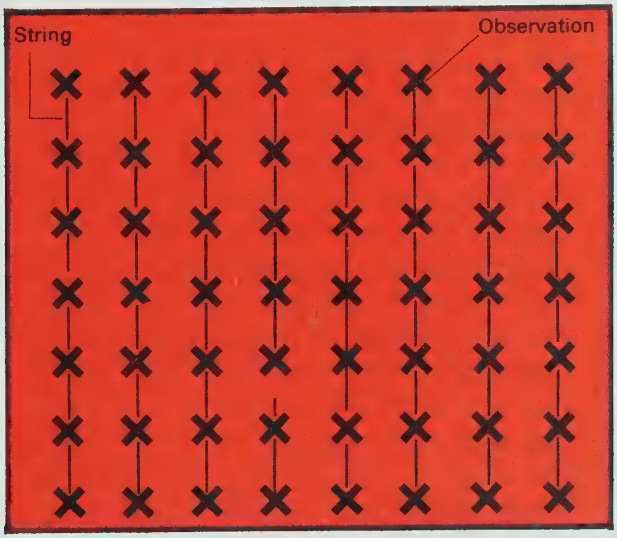
1. The day after the mower came there were still many different kinds of weeds on the field.

2. There were more dandelions than any other plants.

3. There were not many fat hens or groundsel, speedwell, shepherd's purse or stinging nettles.

4. The mower does not really get rid of the weeds because we found a lot on our field.

Diagram showing position of children's observations



The children's method shows that although they realise that the positions of their observations must be widely scattered, they are not yet aware of the need to select their observation points at random, that is, without bias. Also their written work says nothing about their results being a probable representation of the quantities of the different weeds all over the field.

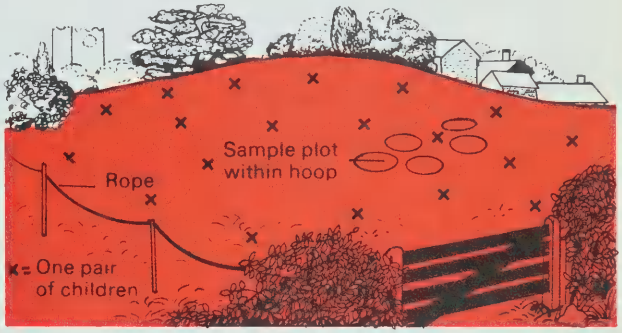
This is only what one must expect. The abstract ideas the children are trying to handle are difficult and first attempts to work with them are likely to result in only partial understanding. Only with more experience will they be able to suggest ways of improving their method.

Presence and absence

This is a very simple sampling method that children can use for finding the frequency with which certain plants occur, for example they might concentrate attention on :

Five named plants in flower in July on some chalk grassland about the size of a football pitch.

Twenty pairs of children each examining five sample plots chosen at random, should be able to obtain sufficient representative data about these plants.



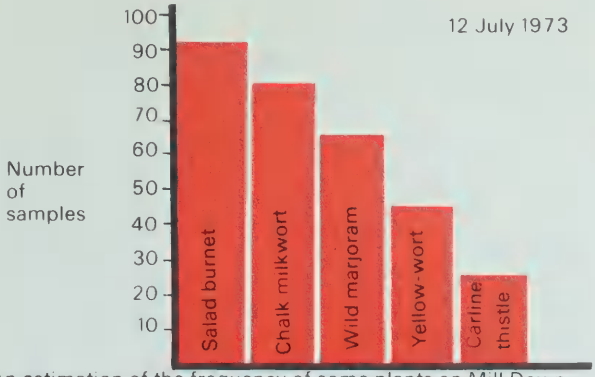
After scattering over the grassland they can select their plots by throwing PE hoops over their shoulders and then each time, on prepared work sheets, record the presence or absence within the hoops of the plants being studied.

Here is an example of a record one pair of children might make.

Date.....	Samples					Totals
Name of plant	1	2	3	4	5	
Salad burnet	✓	✓		✓	✓	4
Wild marjoram	✓	✓		✓		3
Chalk milkwort	✓		✓	✓	✓	4
Carline thistle		✓				1
Yellow-wort		✓		✓		2

Are there any carline thistles in this sample?

On return to school totals from all work sheets can be used in the construction of a class block diagram.



An estimation of the frequency of some plants on Mill Down

Can you suggest another reason for one hundred samples being a good number to study ?

When children are familiar with this sampling method they can use it for making comparisons.

Below, for example, are the results of an investigation of the plants on two plots of similar size, in the same garden, that were treated differently.

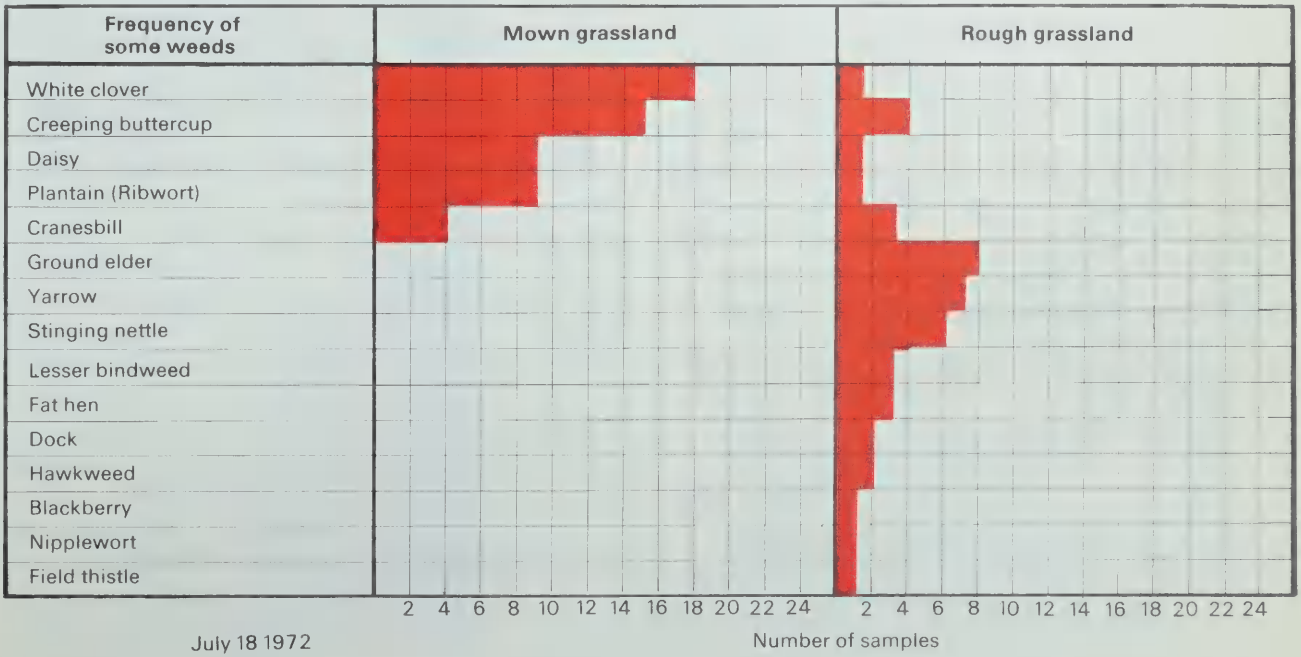
You will find further suggestions for problems that involve counting in this way on page 59.

Creatures from samples from different aquatic conditions

The same number of samples from different stretches of water can be examined for the presence or absence of aquatic creatures that serve as pollution indicators. (See page 58 for further information.)

If the whole class can work in three groups it may be possible to investigate stagnant, slow and fast moving water from a ditch, pond and stream which occur close together.

Five or six pairs of children in each group could each deal with about half a dozen samples of water which they can haul out in similarly sized polythene jars, suspended from lengths of string.



Date.....	Ditch—Stagnant						Totals
Creatures	1	2	3	4	5	6	
Stonefly nymph							
Mayfly nymph							
Caddis larvae							
Fresh water shrimps							
Water slaters	✓	✓		✓			3
Chironimid larvae		✓				✓	2
Rat-tailed maggot	✓			✓			2

Above is a record sheet for one pair of children. Similar sheets will be needed by children sampling the pond and stream. Block diagrams representing the total number of animals found by each group could be compared.

Challenging the validity of the presence and absence method of sampling

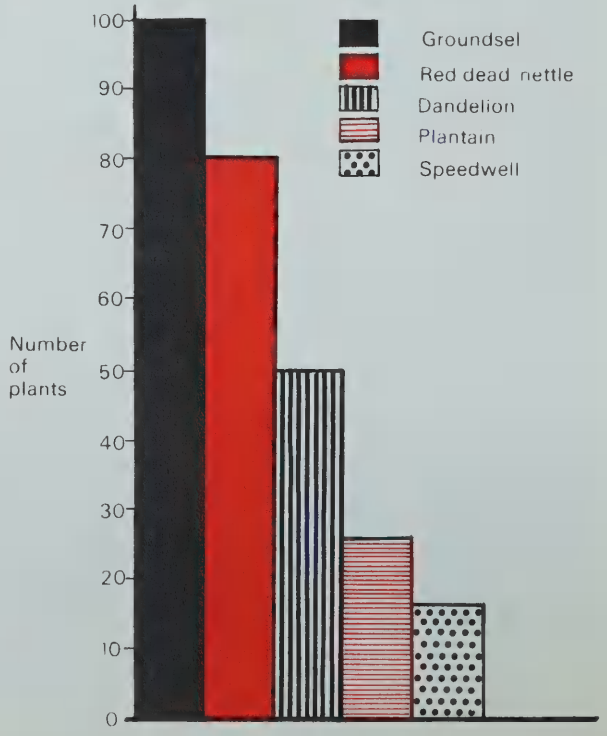
When children have become skilful in using the presence and absence method of sampling, they can be challenged to consider just how representative their results are of the plants and animals actually there.

Situations to serve as a basis for this type of discussion can be devised with models and it may be helpful to describe one way in which this was done.

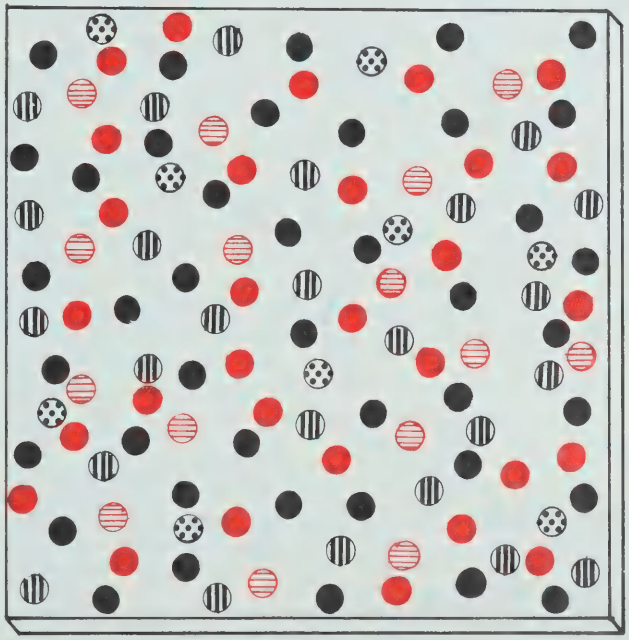
An example

Three squares of softboard (each 60 × 60 cm) were used to represent three areas of land *A*, *B* and *C*, and the same number of coloured map pins were used to represent the plants on each plot.

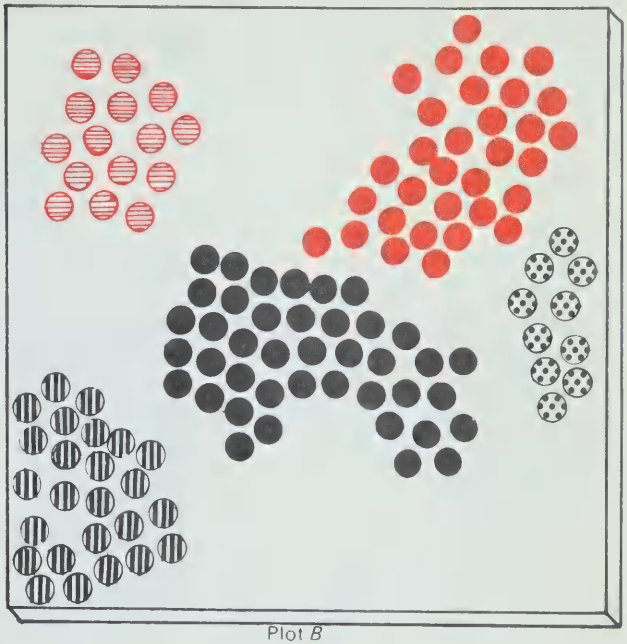
Here is a block graph showing the total numbers of plants present on each plot.



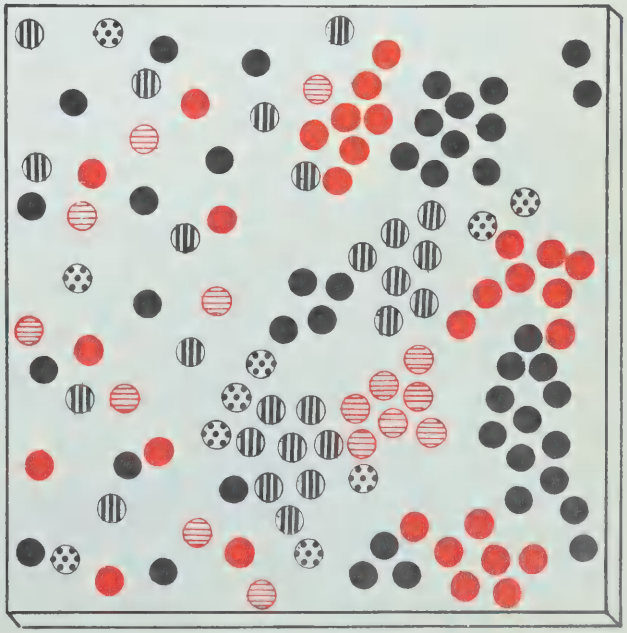
When the pins were arranged on the boards the different distributions of the plants they represented were as follows.



Plot *A*

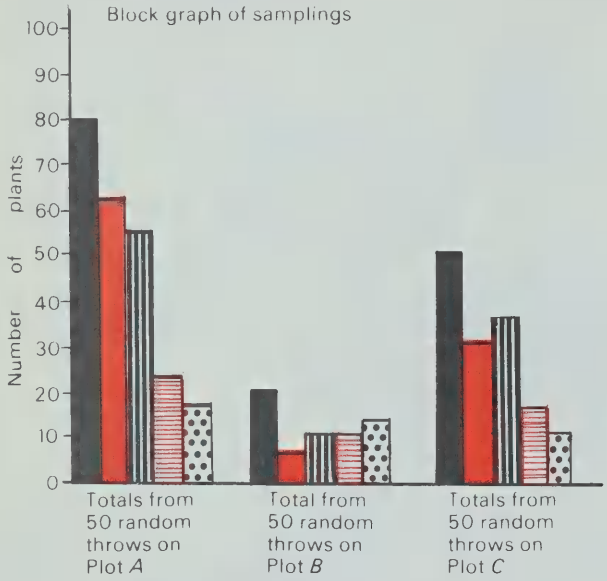


Plot *B*



Plot *C*

Rubber rings from Kilner jars (inner diameter of ring 6·25 cm) were used to represent PE hoops and fifty random throws were made on each plot. The plants enclosed in each of the fifty throws were totalled and the results of these samplings were recorded on block graphs.



From this it can be seen that where plants are closely clumped together as on Plot *B* the method of sampling employed may well give a representation very far from the actual number of plants on the plot.

While a situation like this is being worked out with groups of children it will lead to much more discussion and argument than is usually possible out of doors, and thus also a consequent increase of understanding. On occasions when it is not convenient to leave the classroom, on a wet day for example, children can rearrange pins on the boards and take different numbers of random samples. Discussion of their results will give them valuable experience of interpreting data. This will stand them in good stead when they return to their outdoor investigations. They can also use one of the boards to discover the number of samples necessary to give a good representation of the whole. When this number is exceeded no better representation will be obtained.

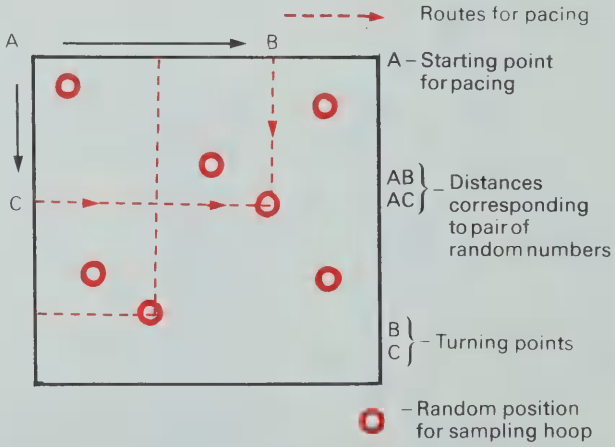
A note on random numbers

Throwing down hoops is still not a completely random method of selecting samples as children can still aim them in certain directions. Two simple methods of obtaining random numbers are described in the guide *Probability and Statistics* (page 36) produced for the Nuffield Mathematics Project, namely :

Rotate a ten-sectioned spinning disc with its sections numbered 0–9. Note where it rests.

Draw from a pack of cards. Ignore the court cards and count the tens as 0. The cards should be shuffled between each draw.

The following diagram shows how two children using a pair of random numbers can pace to a random position on a plot of land.

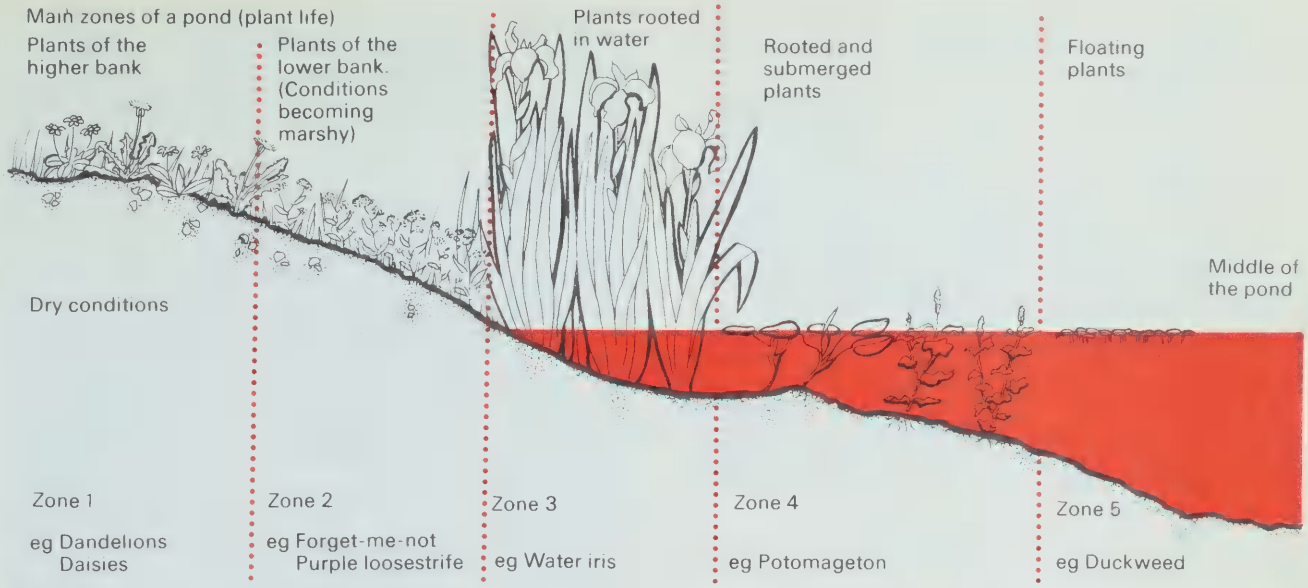


The use of transects

Now it is time to consider another method of sampling that is appropriate to the following conditions.

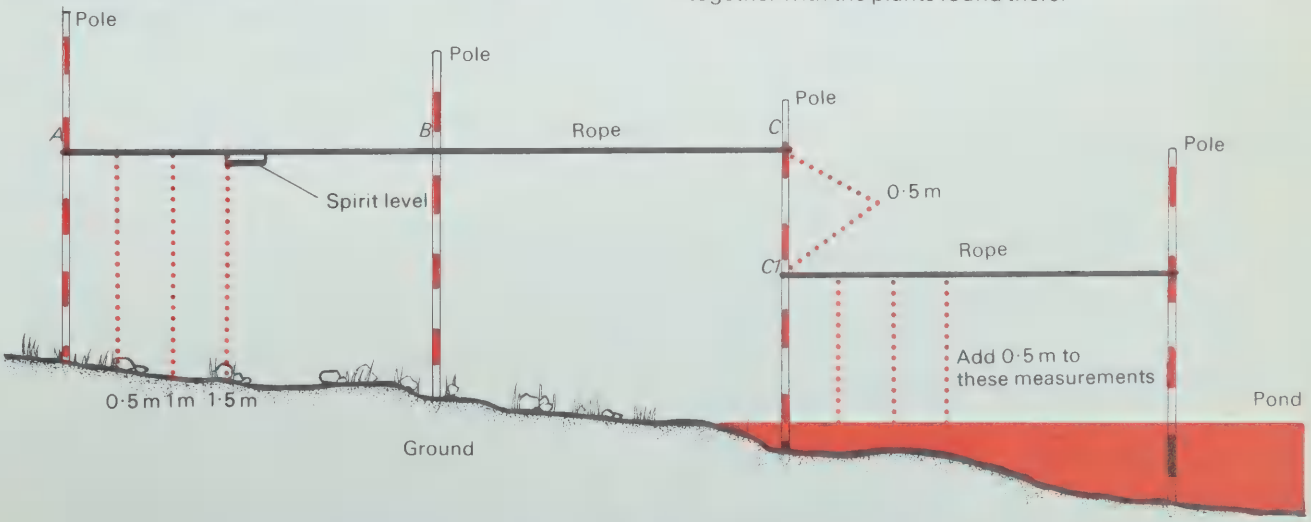
Zonation

Plants and animals may be found distributed in distinct zones or bands. This often happens across a pond where the various depths of the water provide different environmental conditions, and between tide marks on large rocky shores, where areas are covered with sea water for different amounts of time as the tide advances and retreats.



When children wish to sample such areas in order to describe them or to build up records of changes taking place they must include representative parts of each zone in each of their samples. The best way of doing this is by making a representative number of transects, that is, records of vegetation found along straight lines which cross each zone.

The following figure shows how to make a profile, that is, a transect in which the profile or shape of the land is shown together with the plants found there.



Place poles in a line, at convenient distances apart. Fix a rope as shown from *A* to *B* to *C*. Check that the rope is level by hanging a spirit level centrally each time between two poles.

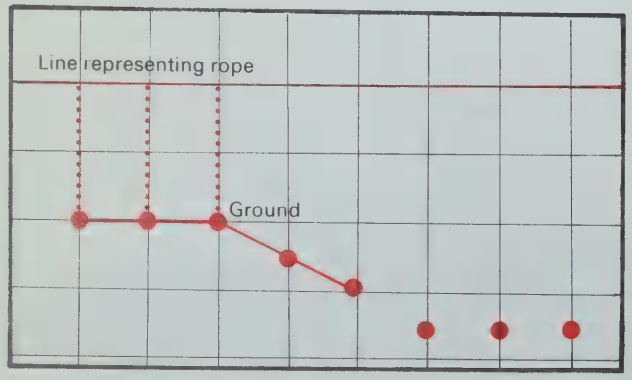
Beginning at pole *A*, measure the distance from the rope to the ground and continue at 0·5-m intervals.

Record the name and height of the plant found at each half-metre interval. Measure the height of the plant in centimetres, and make appropriate entries in a field notebook as shown below.

Distance along (m)	Height of rope above ground	Name of plant	Height of plant
0	—	—	—
0·5	—	—	—
1	—	—	—
1·5	—	—	—

When rope has to be dropped owing to the ground level becoming lower, as at *C*–*C*1, then add the distance *C*–*C*1 on to every following measurement of the distance between the rope and the ground. Make similar adjustments every time the level of the rope is dropped.

Recording on squared paper



Studying changes in plants across land bordering the lake

Draw a line to represent the rope.

Choose a convenient vertical scale then mark out distances from rope to ground as measured at half-metre intervals.

Choose the horizontal scale also. It is usually better to have the horizontal scale smaller than the vertical one.

Join dots to get the outline of the ground.

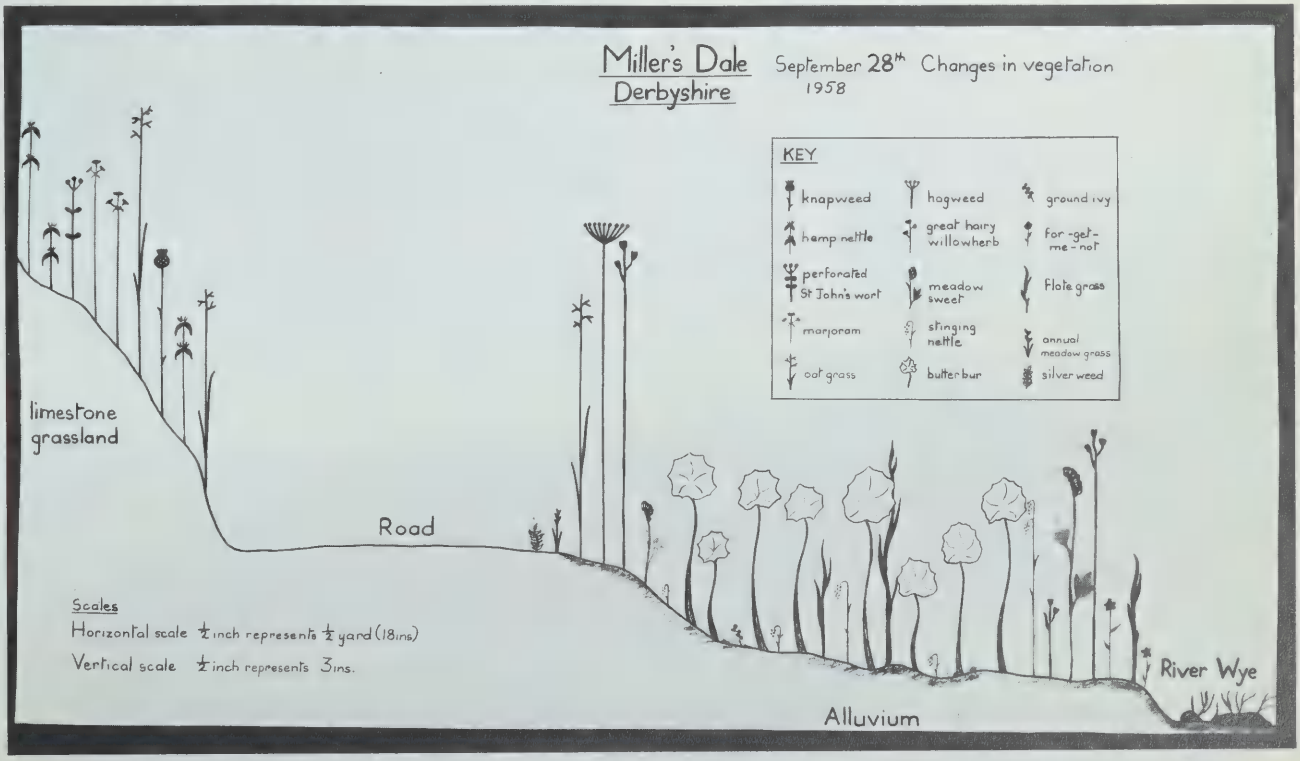
Choose a conventional sign for each plant.

At each half-metre interval draw the plant which occurs there to scale, using the measurements in the field notebook.

Add the key for the plant signs.

The situation in Miller's Dale where data for the transect, recorded below, was collected

Identifying plants found at half-metre intervals along the transect line



A line transect

If children simply want to keep records of the plants occurring at regular intervals in their samples, and have no reason for investigating the shape of the land or the height of the plants, simple line transects can be made by stretching lengths of plastic rope across the area an appropriate number of times and noting the plants growing at each half-metre —or at shorter intervals if the plants are very small and close together.

A line transect taken across 20 m of meadowland in May :

G G D G D B B G B G G Da G G G B B G

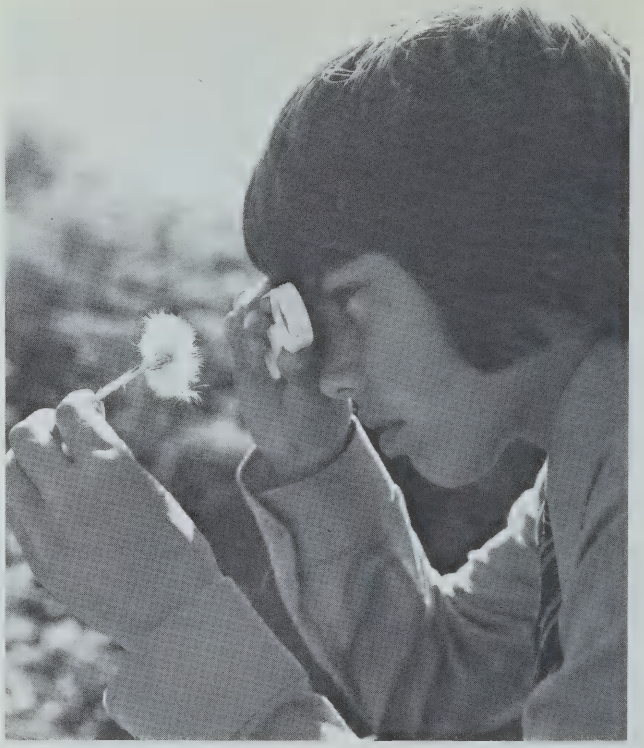
Key
G—Grass
D—Dandelion
B—Buttercup
Da—Daisy

Belt transects

When many of the plants covering the ground are of spreading or rosette types more information can be collected by making belt transects.

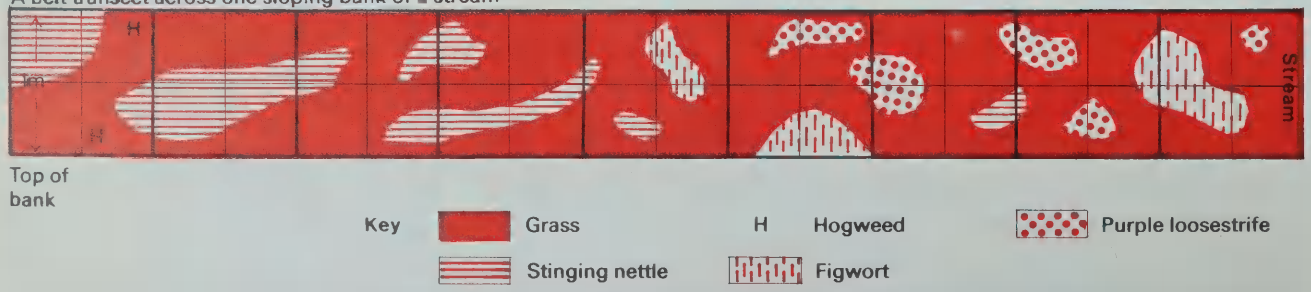
Peg two lengths of plastic line to the ground parallel to each other and 1 m apart. Place two metre rules across the belt also 1 m apart. Map the patches of plants thus enclosed in a metre square in a field notebook using different shading or colours for each type of plant. Capital letters can be used to indicate single plants.

On return to the classroom the records should be transferred to squared paper and an explanatory key added.

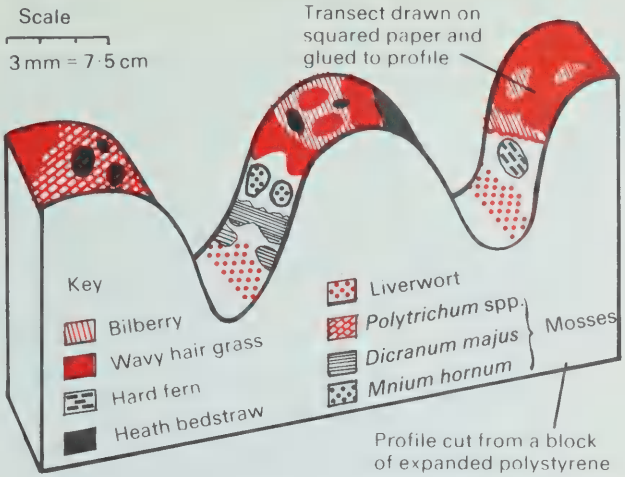


Note. The number of transects to be taken in any one study will depend on the nature of the site to be investigated. What matters is that the number of these samples recorded should be sufficient to represent the study area adequately.

A belt transect across one sloping bank of a stream



A model



In some investigations it may be profitable to obtain measurements from which both a profile of the land and a belt transect of the vegetation can be combined.

Above is a model made by sampling land across which two small streams ran into the River Goyt in Derbyshire.

A study of plants and animals on a rocky shore

Peg out a strip 1 m in width extending between low and high water spring tide levels.

Count and record the animals present in each metre square of this strip.

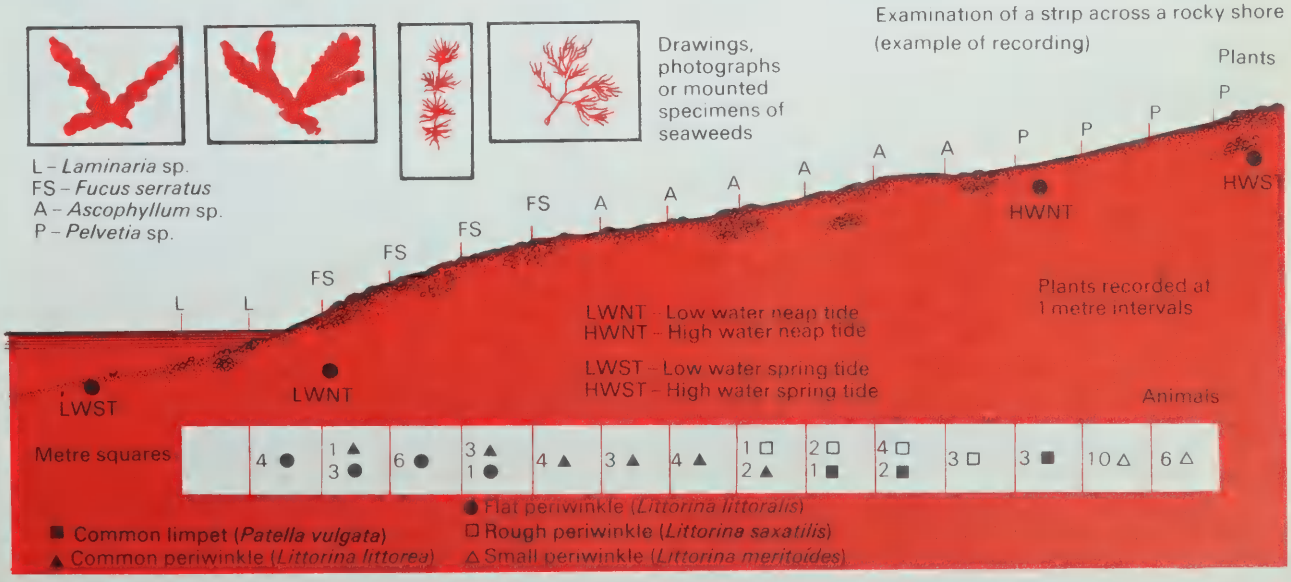
Construct a profile of the shore coinciding with one edge of the strip. Record the plants found at 1-m intervals along this profile.

Mount specimens of seaweeds and relate them to their position on the shore when adding them to the record of this work.

Plant ranging rods at 5-m intervals along the line of the profile. Note the length of time these points remain uncovered between two high tides.

Does there appear to be any relationship between the period of exposure to air and the positions of living things?

Do green, brown and red seaweeds seem to be limited to particular zones of the shore, or is their arrangement more haphazard?


Examination of a strip across a rocky shore (example of recording)
Drawings, photographs or mounted specimens of seaweeds
L – Laminaria sp.
FS – Fucus serratus
A – Ascophyllum sp.
P – Pelvetia sp.
Plants
HWST
HWNT
LWST
LWNT
LWNT – Low water neap tide
HWNT – High water neap tide
LWST – Low water spring tide
HWST – High water spring tide
Plants recorded at 1 metre intervals
Animals
Metre squares
4 ● | 1 ▲ 3 ● | 6 ● | 3 ▲ 1 ● | 4 ▲ | 3 ▲ | 4 ▲ | 1 □ 2 ▲ | 2 □ 1 ■ | 4 □ 2 ■ | 3 □ | 3 ■ | 10 △ | 6 △
● Flat periwinkle (Littorina littoralis)
□ Rough periwinkle (Littorina saxatilis)
△ Small periwinkle (Littorina neritoides)
■ Common limpet (Patella vulgata)
▲ Common periwinkle (Littorina littorea)

3 Environmental factors: methods for measuring weather conditions

What do we really mean by a strong wind or a gentle breeze ?
How shady is this shade ?
How much rain fell last night ?
How hot or cold is the water in this puddle ?

These are the sort of questions that children must soon tackle when they become interested in finding out whether differences in environmental conditions correspond in any way to differences in the quantities of the plants and animals they can discover in various places.

They are questions that can be answered either by discovering *how much* more or less there is in one situation compared with another, or by matching what is found against either an arbitrary or a generally recognised scale—in other words, by measuring.

Measuring equipment

Many useful arbitrary measurements can be made at first with home-made equipment. These measurements will necessarily be approximate. Later, measurements in generally recognised units may be required to establish beyond doubt the existence of small differences and the need for more sophisticated measuring instruments arises.

Then the teacher must decide whether children who wish to tackle investigations they do understand should be allowed to collect some of their information by means of measuring devices based on scientific principles still beyond their experience.

It does not seem unreasonable to permit young children of between six and seven years to use thermometers before they have studied ways in which heat can affect the volumes of liquids.

After all, many people who do not understand internal combustion use cars. Similarly a light-meter can provide an investigator who knows little or nothing about its components with very useful information about the strength (intensity) of light falling on different parts of a site. However, any instruments children use as a means to an end should be ones that they can learn to handle and read for themselves. They will soon lose interest in any study that involves waiting and watching while their teacher manipulates a 'black box' and merely gives them the answers.

The date and time of observations should be included in *all* records.

Information about prevailing climatic conditions can only be obtained when measuring equipment can be left on the site and observed regularly.

When this is impossible the records from the Meteorological Office might be used, since these cover most of Britain. Further information and sometimes contacts with local observers can be obtained free of charge by getting in touch with :

The Director
The Meteorological Office (MO3)
Headstone Drive, Harrow, Middlesex.

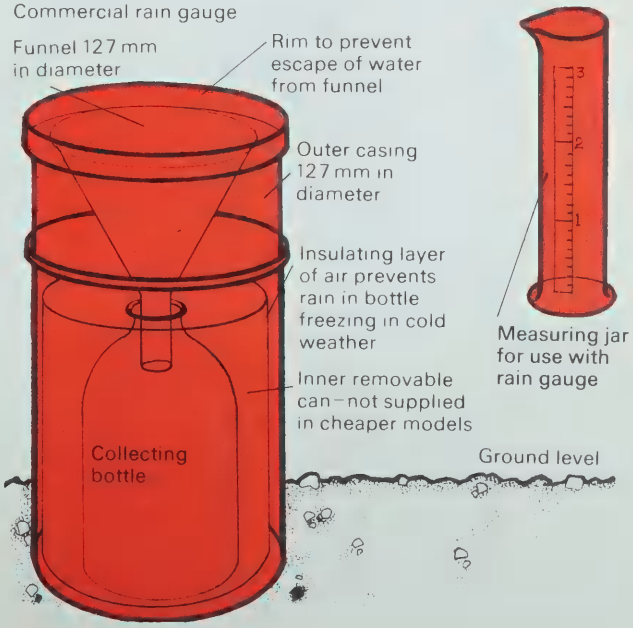
The weather conditions during isolated visits to a study area are often worth recording, for they may be influencing things such as the number of insects pollinating flowers, or the distances seeds and fruits attached to plumes can be carried on that particular occasion.

Rainfall

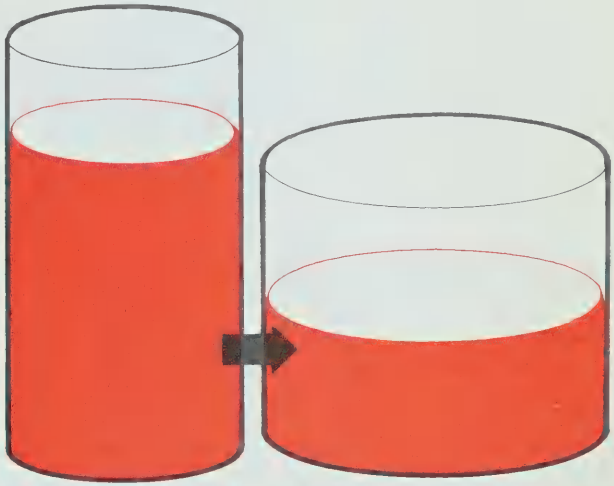
From earlier experience children will know that water is necessary to living things but not always in the same quantity. Therefore the amount of rain which falls on a site may create conditions that suit some plants and animals but not others.

Arbitrary amounts of rain falling on representative samples of the site can be collected in home-made rain gauges. Ways of making this useful piece of equipment are described in Volume 2 Part 2, pages 4–6, together with information about its use.

The time will come when older junior children will find knowledge of the standard method in use for recording rainfall very useful. This will enable them to produce local records that can be exchanged for comparison with those from schools in other parts of the country. The method can best be explained by referring to the following illustration of the type of commercial rain gauge in use at standard meteorological stations.


Commercial rain gauge
Funnel 127 mm in diameter
Rim to prevent escape of water from funnel
Outer casing 127 mm in diameter
Insulating layer of air prevents rain in bottle freezing in cold weather
Inner removable can – not supplied in cheaper models
Collecting bottle
Ground level
3
2
1
Measuring jar for use with rain gauge

It is usual to express the amount of rain that accumulates in the collecting bottle in a given time as the depth in centimetres (or inches) it would reach if transferred to the base of the outer casing of the rain gauge. This is the depth of rain falling on ground equal in area to the mouth of the collecting funnel.



Measuring jars, graduated to indicate directly the depth rain from the collecting bottle would occupy if placed in the outer casing, can be purchased for use with commercial rain gauges. Such a jar can only be used with rain gauges of the diameter for which it has been calibrated. The usual diameter of commercial rain gauges is 127 mm (5 in).

In describing rainfall we might say '*x* cm of rain fell on the site in twenty four hours'.

Are samples from a rain gauge typical of what falls over the whole site under investigation ? To test this children could place similar gauges in different places and compare their contents after a given period.

Wind speed and direction

For methods of making observations and estimations see Volume 2 Part 2, pages 11–17.

The evaporating power and humidity of the air

These two conditions are closely associated.

When air moves above the surface of water it helps water to change to water vapour. This is called evaporation. Humidity is the amount of water vapour in the air at any time. Air containing as much water vapour as it can hold is described as 'saturated' and its humidity is a hundred percent. In such a state air has no evaporating power, so cannot cause drying. When the air is dry, that is, when humidity is low, its power to bring about evaporation or drying is great.

Other factors affecting the air's evaporating power are the rate of its movement and its temperature.

Children's early experience of evaporation and humidity will probably be gained from :

Measuring the gradual reduction in size of puddles.
Hearing complaints about 'a poor dry' for the washing.
Feeling hot and sticky when the air is humid because there is little evaporation of perspiration from their skin, and therefore little or none of the cooling this causes.

This is the sort of experience that will help them to become curious as to whether movement of wind and the state of the air is causing too much or too little water to leave living things and their surroundings.

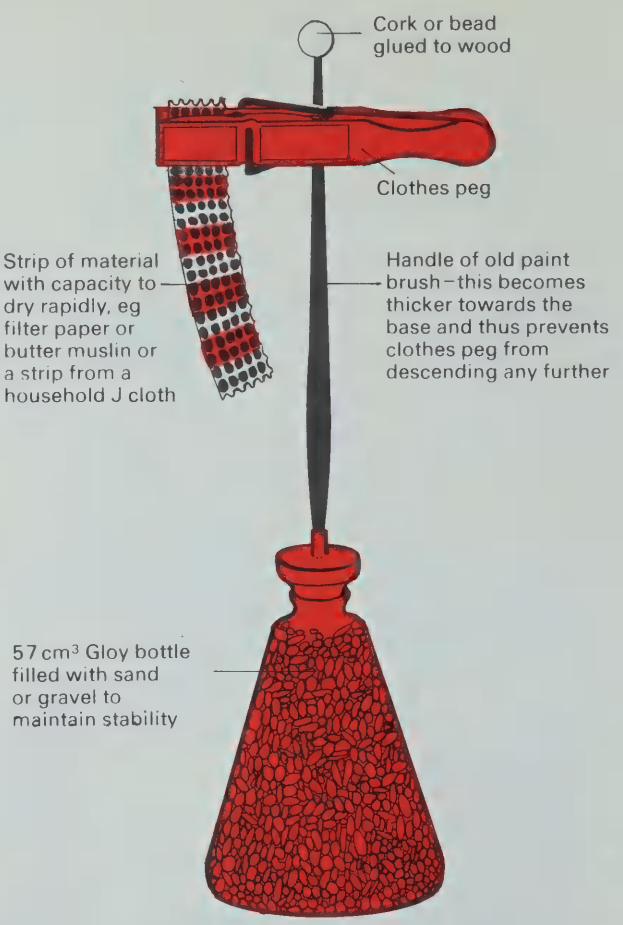
Atmometers

At this stage children will probably find it easier to begin by investigating the rate at which air causes drying up than to estimate or measure its humidity. They can compare arbitrary amounts of water evaporated during different periods of time or in different places by means of a home-made device called an atmometer.

Here are some suggestions for making atmometers.

A simple atmometer

Soak a strip of material in water, then press it between two pieces of blotting paper to remove surplus moisture. Suspend the strip from the clothes peg. Note the time required for it to dry in the surrounding air.

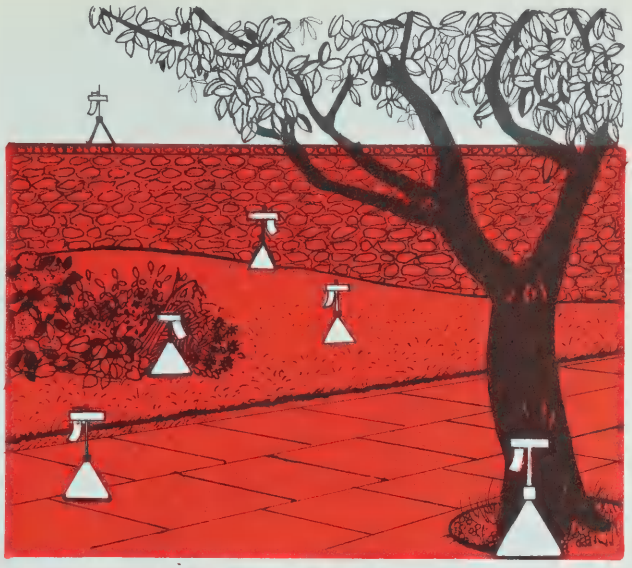

Cork or bead glued to wood
Clothes peg
Strip of material with capacity to dry rapidly, eg filter paper or butter muslin or a strip from a household J cloth
Handle of old paint brush – this becomes thicker towards the base and thus prevents clothes peg from descending any further
57 cm³ Gloy bottle filled with sand or gravel to maintain stability

A micro-atmometer

A micro-atmometer is also very useful. It gives more precise information than the previous model by supplying an arbitrary measurement of the time air takes to evaporate a single drop of water.

Directions for making one are given in *Outdoor Biology*, Book 3, pages 58–61, by O. N. Bishop (John Murray, 1972).

A number of children could make simple atmometers and place them in various positions on a site as shown in the diagram. The rates at which the air is causing evaporation in different parts of the area can then be compared.



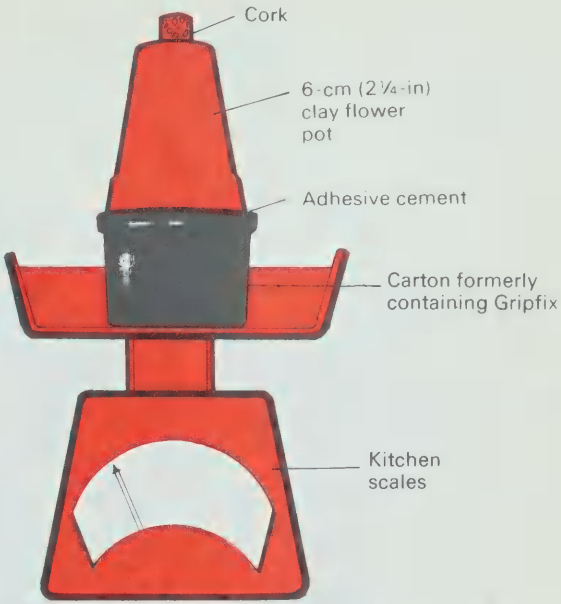
Arrangements for longer periods of time

Apparatus may be constructed in which large quantities of water are placed in contact with surfaces from which this water can then be evaporated. Changes in the rate of evaporation over longer periods of time can then be measured.

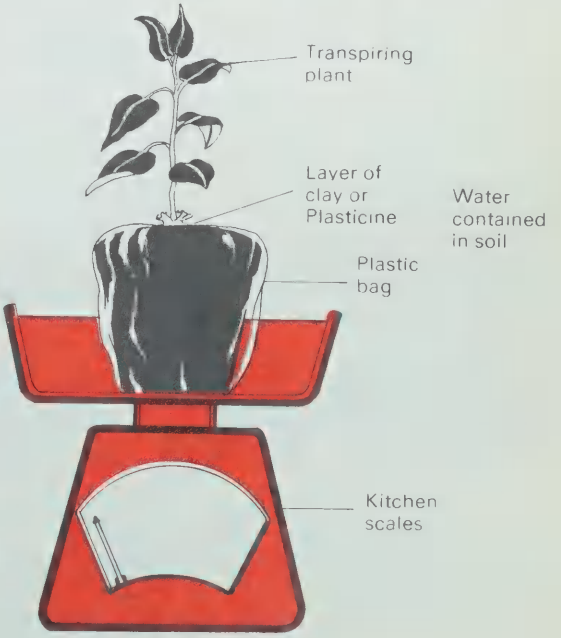
Glue the porous clay flowerpot and Gripfix carton together with an adhesive cement impermeable to water. Test to make sure that the joint is watertight. Fill the apparatus with water and leave it until the walls of the flowerpot become saturated. Top up the water in the apparatus and insert the cork. Place on a scale pan and note the position of the pointer on the dial. The air around will cause evaporation to take place from the porous surface of the flowerpot and so there will be a reduction in mass indicated by the amount of movement of the pointer.

A transpiring plant can be used instead of the inverted flowerpot and carton. The plastic bag and layer of clay (or Plasticine) prevent the water escaping from the pot and soil. Thus water can only be lost by evaporation from the leaf surfaces. As this happens the pointer on the dial will move and so indicate a reduction in mass corresponding to the amount of evaporation caused by the wind.

In these arrangements the positions of the pointers should be recorded at hourly intervals.

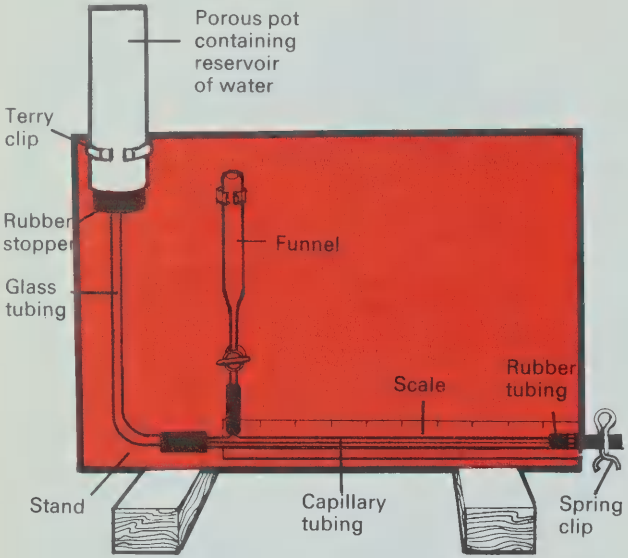


The distance between two neighbouring marks on the dial can be regarded as one unit for recording purposes.



A potometer

A botanical potometer can be adapted for use as an atmometer if a transpiring plant is replaced by a porous pot (obtainable from main suppliers of scientific equipment) filled with water.

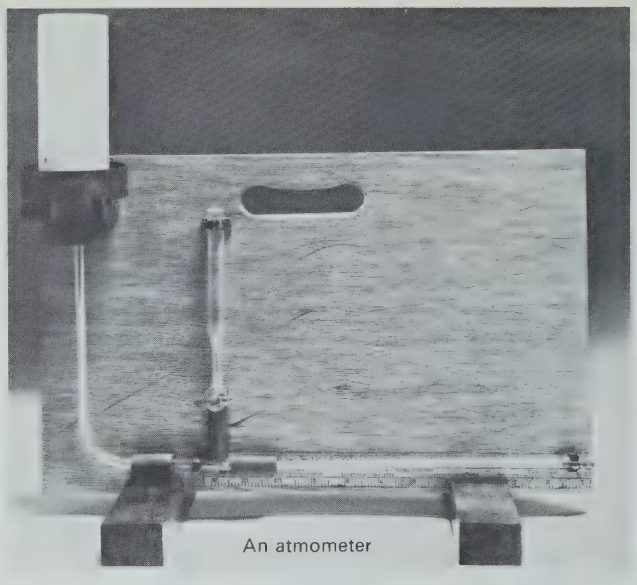


Mount this apparatus on a wooden stand so that it can be set up easily in various outdoor places. Fill it with water via the funnel and make sure all air bubbles are eliminated. Release the spring clip for a moment in order to introduce a small air bubble into the end of the capillary tubing.

As water is evaporated from the porous surface of the pot the bubble will be drawn along the tubing and the distance it travels in a given time can be recorded.

Atmometers with porous pots should be filled with distilled water because the chemicals in tap water will soon fill interstices in the porous material and reduce evaporation. If distilled water is not available the pots should be replaced frequently.

After setting up an atmometer, time (ten to fifteen minutes) should be allowed for the temperature of the equipment to reach a steady value in relation to that of the surrounding air before any observations are made.



An atmometer

Wind speed constantly fluctuates because gusts alternate with slower movements. Therefore a measurement relating to a long period of time, or the average of a number of observations, will give a better indication of the air's evaporating power than a single observation made rapidly.

Humidity

Seaweed can serve as an arbitrary indicator of the humidity of the air. Suitable species are : *Ascophyllum nodosa, Fucus serratus, Fucus vesiculosus, Laminaria saccharina.*

Suspend the plant so that air can circulate freely around it. Make sure that it is shielded from rain and sunlight. Feel it at regular intervals.

Humidity of the air	Evaporation of moisture	State of seaweed
Low	Rapid	Dry and hard
High	Slow	Soft and flabby
Saturated	None	Soft and flabby

Can the air take up much more water?

The boy in the photograph has suspended a humidity meter from the lower branch of a bush to find out more about the air surrounding plants growing beneath it.

This instrument is produced commercially for use in greenhouses by Brannan Thermometers, Cleator Moor, Cumberland, at a cost of £2·00. It gives direct readings of the relative humidity of the air.

To use this instrument, hang it so that air under investigation can circulate freely around it for fifteen to thirty minutes so that it can come into equilibrium with the surrounding air.

Note the position of the pointer on the scale. Readings will not give children the absolute quantity of water in the air at that time. A reading of say 20 on the scale would mean that air has taken up to twenty percent or one-fifth of the quantity of water vapour it would contain when saturated at its present temperature. It would therefore be very dry and capable of taking up much more water vapour from the surfaces of plant leaves, human bodies, or puddles, thus causing them to dry up rapidly.

The intensity of light

Children may get interested in the effects of light and darkness when they discover phenomena such as these :

Yellow grass under stones.
The tendency of green leaves to take up a position perpendicular to the light source.
The difference in the sizes of leaves of the same species of plant growing under shady and sunny conditions.
The poor sight of some subterranean creatures, for example, the mole.
The fading of the colours of materials in strong sunlight.

Measuring the actual strength and quality of the light is a complex business, but some useful information indicating how much more light one place receives than another can be collected quite easily by arbitrary methods.

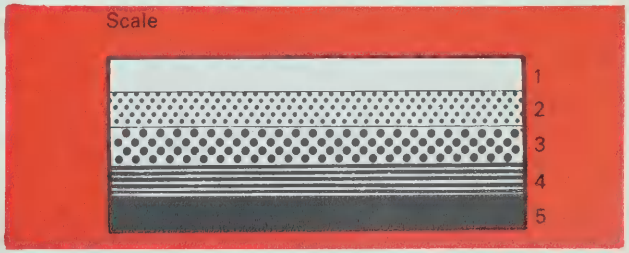
Using paper sensitive to light

Blueprint paper is useful for this purpose.

Source of supply :

Entwhistle Phort and Co Ltd
Tudor Industrial Estate
Ashton Street
Dunkenfield, Cheshire.

Begin by making a scale.



Expose strips of blueprint paper of similar size to the same sunlight for periods of 5, 10, 15, 20, 25 seconds. Fix the results by placing the papers in a dish of fixing solution made by dissolving 150 g of sodium hypochlorate in 500 ml of distilled water (10 minutes).

Wash papers in running tap water for 10 minutes. Dry them and paste them in order of intensity of colour on a piece of card ; give each one a number.

To compare the amounts of light falling on different places expose similar areas of blueprint paper for 10 seconds in each place and match the results against the scale. If records of these results are required, the papers must be fixed and washed immediately their periods of exposure end. Comparisons with the scale can then be made after drying.

Children might try working with sensitive photographic paper if any difficulty in obtaining blueprint paper is experienced.

They will find Kodak Contact Paper C145 suitable for handling because it does not respond as rapidly on exposure to light as the more commonly used photographic papers.

After exposure this paper should be treated with the usual commercial developers and fixatives.

Using a photographic exposure meter

This instrument measures the amount of light *reflected from* the surfaces of different things. It contains a photo-electric cell. The extent to which this cell is affected by different intensities of light is indicated by a pointer on a scale on the opposite side of the meter. Figures on this scale can be used as arbitrary measures of the strength of light.

Begin investigations by obtaining a reading for light reflected from a plant, exposed to full daylight. Place a sheet of paper with a matt surface such as cartridge paper (Imperial size) on the ground beside the plant. Hold the meter with its light-sensitive cell facing the paper but about 1 m from it. Record the position of the pointer.

Then take readings in the same way in other places and decide whether these indicate the intensity of the light to be $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{3}$, etc, that of full daylight.

Note that the delicate internal mechanism of this instrument can be damaged by holding the photo-electric cell facing direct sunlight, or by dropping or knocking the meter violently.

Temperature

Information about the heat or cold to which living things are exposed can be obtained by measuring the temperature of the surrounding medium. This may be air, soil or water.

The temperature of the air

Hang a Celsius or a maximum and minimum (Six's) thermometer in a position sheltered from strong winds or the direct heat of the sun.

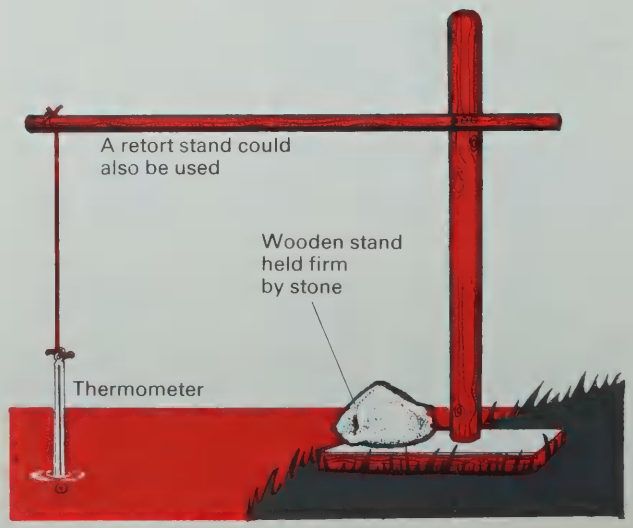
Allow the Celsius thermometer to take up the temperature of its surroundings (15 minutes). Read it at regular intervals during a visit to the site or at the same time daily. The times of taking readings should be recorded carefully.

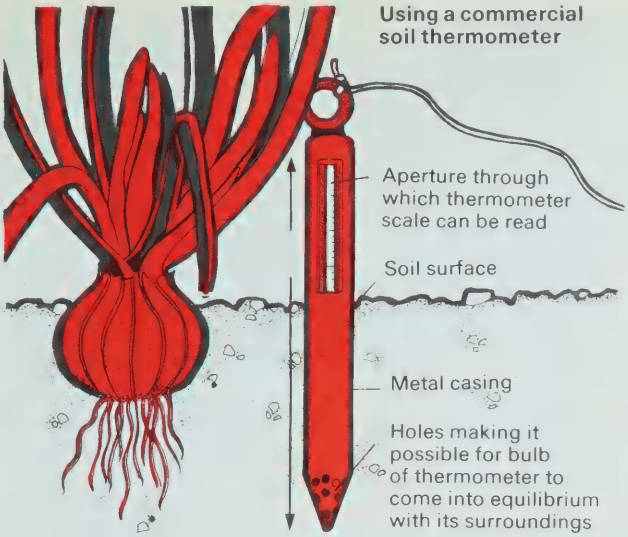
The maximum and minimum thermometer indicates the highest and lowest temperatures of the air over a period of 24 hours.

The temperature of soil and water

Surface level

Suspend a Celsius thermometer so that its bulb is just below the surface of the soil or water. After allowing time for it to come into equilibrium with its surroundings note the reading on the scale.




Aperture through which thermometer scale can be read
Soil surface
Metal casing
Holes making it possible for bulb of thermometer to come into equilibrium with its surroundings

Using a commercial soil thermometer

Information about conditions in soil and water lower than 30 cm might be obtained in the following ways.

An arrangement for soil

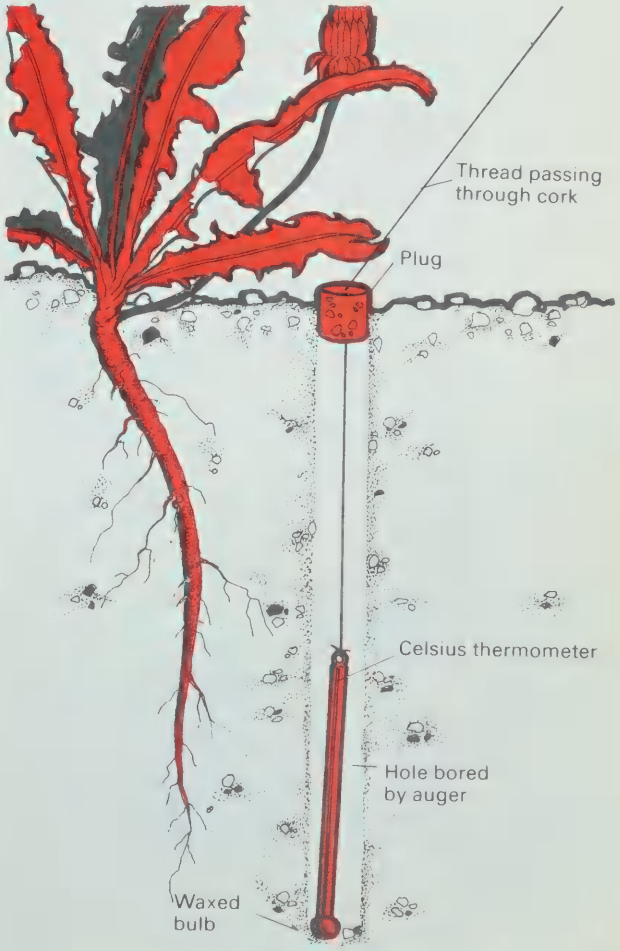
Screw a soil auger into the soil to the depth required.

After covering the bulb of a Celsius thermometer with wax to slow down heat loss, lower it into the hole. Close the opening made by the auger at ground level with a cork.

Allow time for the thermometer to reach the temperature of its surroundings.

Remove cork and raise the thermometer quickly to take its reading.

If conditions around a root system are being investigated, repeat this process on different sides of the plant.

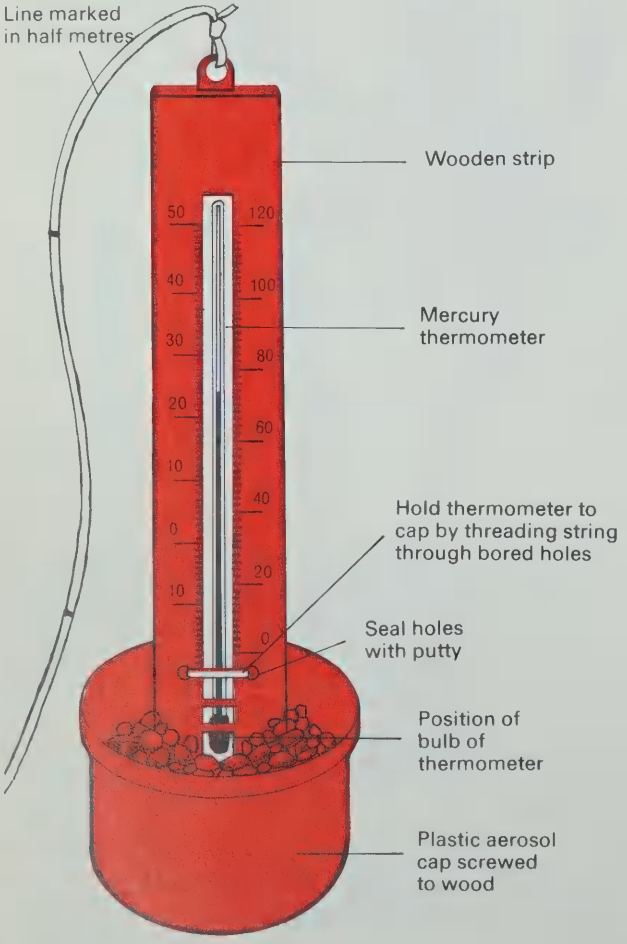


An arrangement for water

Two holes can be bored in the plastic cup with a hot steel knitting needle in order to screw it to the wooden strip.

By means of the line marked in half metres, lower the bulb of the thermometer to the required depth. One or two pebbles in the cup will help it to sink.

After allowing sufficient time for the thermometer to adjust to its surroundings, raise the apparatus and read the temperature while water from the depth investigated still surrounds the bulb.



Noting the temperature of a sample of water hauled from three metres below the surface of the lake

Does the temperature of the soil and water close to the surface level change more frequently than that at greater depths ?

At what depth are creatures inhabiting the lake likely to find the warmest places during the winter months ?

Do earthworms gather in the lowest parts of their burrows in winter because it is warmer there than at ground level ?

Making use of electricity

Teachers interested in electricity may like to construct two more instruments that children can use to compare intensities of light and temperatures.

Now that workshop facilities and instruction are available in many Teachers' Centres, teachers are finding more opportunities for working together on projects such as these and thus increasing their own knowledge. Children of thirteen will not be ready for the experience which could enable them to understand the scientific principles on which the designs of these two pieces of equipment are based. But (as in the case of the commercial humidity indicator described on page 37) they can employ them as useful tools, because they can learn to operate and read them very easily.

A light-meter

This is the instrument recommended in *Teachers' Guide* III (Nuffield Biology), pages 174–5 (Penguin, 1966). It can be used for making comparisons of the total illumination in different places.

Construction of the instrument

Components required	Suppliers	Approximate cost
Low-voltage cadmium sulphide (CdS) cell (ORP12 Type 1 or 2)	Mullard Ltd	45p
Micro-ammeter (0–500)	G. W. Smith and Co (Radio) Ltd	£2·50–3·00
Potentiometer with range 1 500–6 800 Ω	R.S. Components Ltd	45p
Toggle switch (on/off)	Woolworths	29p
1·5-V battery	Woolworths	6p
Connecting wire	Woolworths	20p (packet)
Flex	Woolworths	37p (packet)

Suppliers of components and materials

Teachers can obtain the components and materials required for the two instruments described in this section from the following suppliers :

Mullard Limited, Mullard House, Torrington Place, London WC1.

G. W. Smith & Co. (Radio) Limited, 11–12 Paddington Green, London W2.

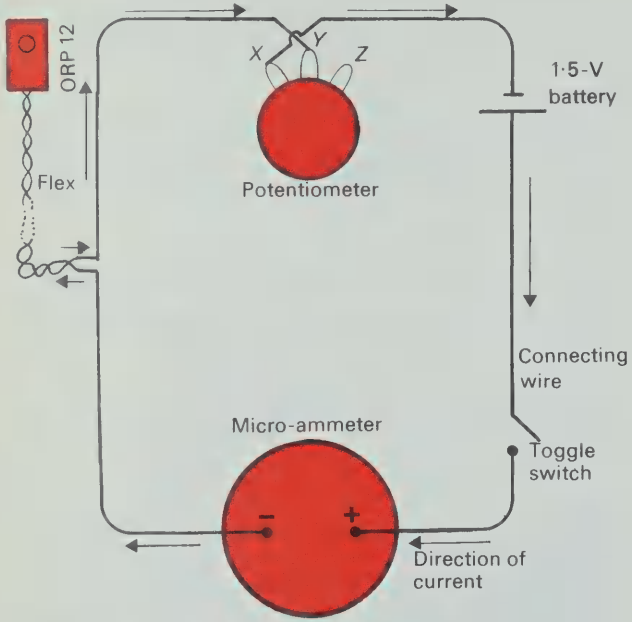
R.S. Components Limited, 13–17 Epworth Street, London EC2.

Philip and Tacey Limited, North Way, Andover, Hants.

Morol Limited, 21 Woodthorpe Road, Ashford, Middlesex.

A meter for comparing the total amount of light received in different places

The previous photograph and this diagram shows how these components can be connected in series (by soldering) and enclosed in a box for safe transport to outdoor sites.



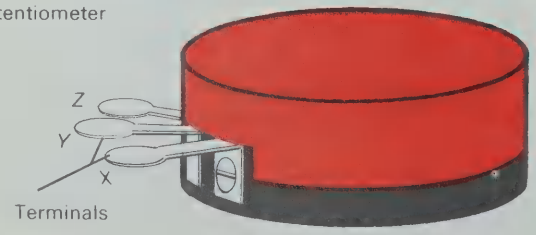
Components of light-meter attached to board and connected in series

Explanation for the teacher

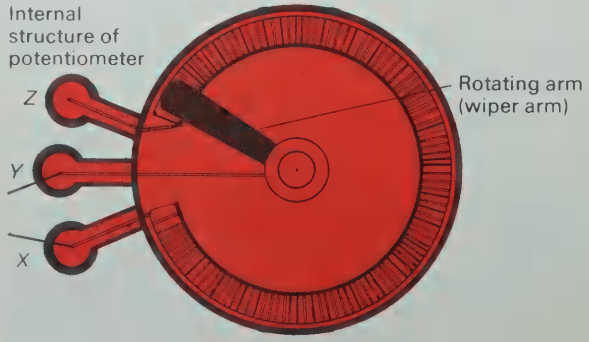
When the instrument is switched on and the CdS cell is exposed to light, the current flowing round the circuit will cause a deflection of the needle of the micro-ammeter to the right. If there is very little resistance to this current, its magnitude may be too much for the micro-ammeter to record and the needle will then swing beyond the highest point on its scale. This could harm this delicate instrument so use should be made of the potentiometer to reduce the current and prevent any damage.

The type of potentiometer used in this light-meter contains a bare wire of a special alloy whose resistance is not affected to any extent by changes of temperature. This wire is wound round a non-conductive ring. Only two of the three terminals as seen in the illustration are used.
X leads to the beginning of the wire coil and *Y* is connected to a wiper arm that can be rotated.

A potentiometer



Internal structure of potentiometer



By turning the black knob that appears just above the micro-ammeter in the photograph on page 41, the wiper arm can be rotated so that the contact at its free end is moved along the coil of resistance wire. The arm is turned to a position where it selects sufficient resistance to the current flowing round the circuit to bring the micro-ammeter needle back to a convenient reference point on the scale. When the needle reaches this point, stop turning the black knob.

Here the potentiometer has been made to function as a simple variable resistor. Note that this can be done by connecting it into the circuit by terminals *X* and *Y* only. Another arrangement in which connections are made with all three terminals of a similar potentiometer is described on page 46.

If the resistance of the potentiometer is now kept constant the CdS cell is left as the only other component in the circuit capable of causing the magnitude of the current flowing in the circuit to change. The CdS cell is the photo-resistor, which means that its opposition to the flow of electricity round the circuit changes according to the amount of light to which it is exposed. For example, in darkness the cell's resistance to the current is 5 megohms ; in bright daylight its resistance falls to 500 ohms. Therefore, when this cell is exposed to different intensities of light, the variation in its resistance to the flow of electricity will affect the magnitude of the current, and consequently the needle will be deflected accordingly. This deflection enables us to compare the amount of light received in different places.

Children using a light-meter
Children should learn to carry out the following procedure.

Expose the CdS cell in the strongest light available. Switch on. Adjust the instrument to read 500. Switch off the current.

Then expose the CdS cell to other places where information about the intensity of light is required and each time record the position of the needle.

By comparing the different readings of the needle it is possible to get a measure of the relative intensity of the

Children using a light-meter

light falling on the different areas investigated. For instance, if the second reading was 400 compared with the reference point of 500 the value of the current is 20 percent lower. This does not mean that the difference between the two light intensities is also 20 percent but that it is possible to arrange the series of measurements made in order of light intensity.

General information
Certain things, such as the frequent disappearance of the sun behind clouds, can cause the intensity of light in a place to vary while a reading is being taken. If the intensity of light is constantly fluctuating a number of readings should be taken at regular intervals for half an hour and an average calculated. The best conditions for making comparative measurements are provided by sunny days when the sky is free from clouds, or when the sky is uniformly grey. Teachers should discuss these considerations with children as they work out of doors.

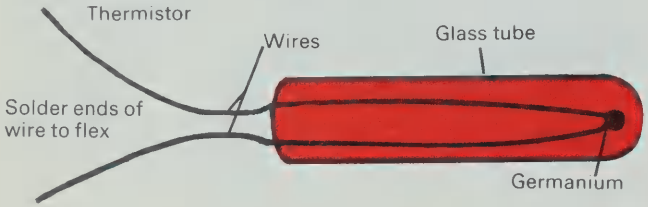
At a later stage when children are ready to be more critical of their own efforts, they may be interested in taking other factors affecting the amount of light and its quality into account and improve on their investigations accordingly.

Suggestions for doing this can be found in the *Teacher's Guide* III (Nuffield Biology), pages 114-115 (Penguin, 1966).

Using a thermistor

A thermistor is an example of a variable resistor ; its resistance to an electric current and therefore the voltage drop it can bring about when a current is passing through it varies with the temperature to which it is exposed.

A suitable thermistor for the equipment to be described is listed in suppliers' catalogues as Th. B–12. It consists of a small bead of germanium encapsulated in a small glass tube from which two wires protrude.



The resistance of germanium increases as it is cooled and decreases as it becomes warmer, within the limits of its capacity to respond. In this it differs from metals : their resistance increases as they get warmer and decreases as they cool.

The advantage of using a thermistor for monitoring changes in temperature is that it can be attached to a length of plastic-coated flex and placed at different depths in soil or water. Its response to different temperatures over a given period of time can then be discovered without removing it. This is done by plugging the other end of its flex into a box containing a control unit which can be manipulated to provide the required information.

Material for the box

One piece of wood 20 × 15 × 1 cm.
Two pieces of wood 20×7×1 cm.
Two pieces of wood 13×7×1 cm.
One piece of Perspex (or wood) 20×15×0·3 cm.
Four rubber plugs for glueing to the Perspex (or wood) to serve as feet separating it from the surface on which the box rests.
Some small brass screws.
Araldite.
Thin sheets of Vinyl or Contact patterned to represent wood can be glued to the surfaces of the box to improve its appearance.

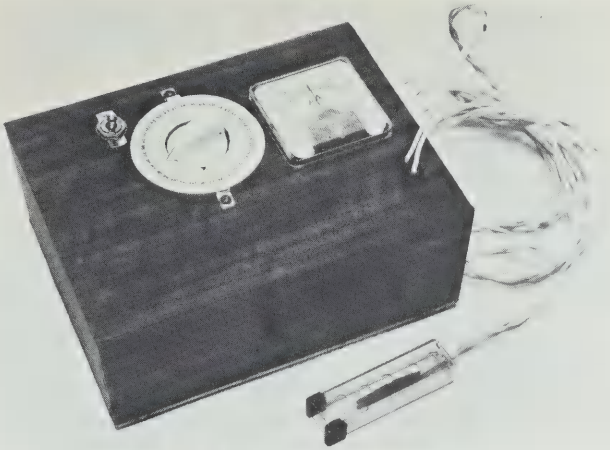
Construction of the instrument

Components required	Suppliers	Approximate cost
Fixed resistors 15kΩ	R.S. Components Ltd	2p each
10kΩ		
680Ω		
Potentiometer 10kΩ		45p
Pre-set resistor 1·2k Ω		20p
Bead thermistor Th–B12		75p
Pointer knob		66p
50–0–50 micro-ammeter	G. W. Smith and Co Ltd	£2·85
360° protractor to serve as a scale. Made from polar co-ordinate graph paper covered with Moroseal	Polar graph paper from Philip and Tacey Ltd Moroseal from Morol Ltd	61p for 25 sheets
1·5-V cell (U2 type)	Woolworths	6p
2-pin plug		5p
Toggle switch (off/on)		29p
Connecting wire		20p (packet)
Lighting flex		37p (packet)
Plastic-coated Terry clip to hold battery	Do-it-yourself shop	

The thermistor as a probing device

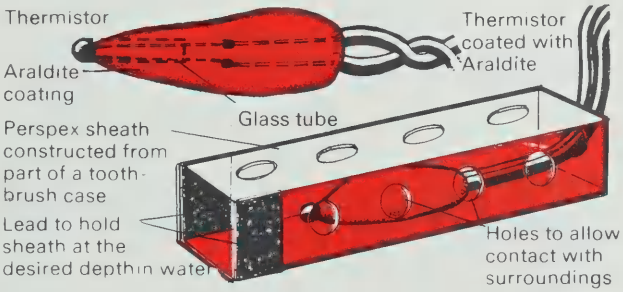
Expose the two wires at one end of the length of flex and solder these to the two wires protruding from the thermistor. Completely surround these joints and most of the glass enclosing the thermistor with a coating of Araldite to serve as an insulating layer, but make sure the bead of germanium remains exposed.

Further protection of the exposed end is required to prevent damage when pushed into soil, or when in

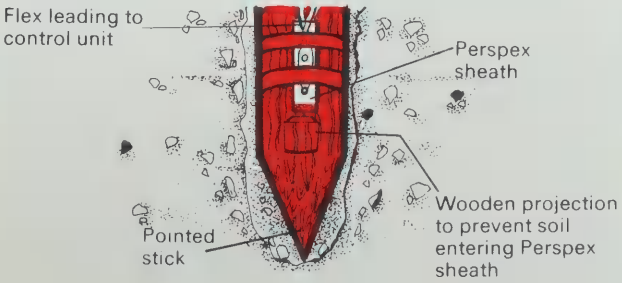


Thermistor connected to a control unit

contact with large stones on the bed of a stream. However this must not prevent contact between the thermistor and the surrounding medium.


Thermistor
Araldite coating
Thermistor coated with Araldite
Glass tube
Perspex sheath constructed from part of a tooth-brush case
Lead to hold sheath at the desired depth in water
Holes to allow contact with surroundings

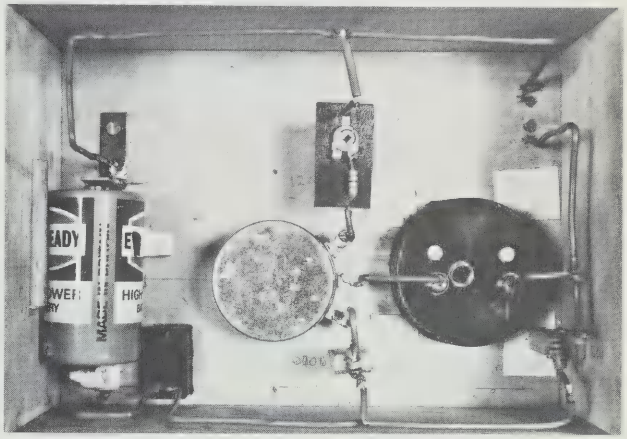
The flex and Perspex sheath can be lashed to a pointed stick for pushing the thermistor into a hole in the soil made with a soil auger. No soil should enter the open end of the sheath.

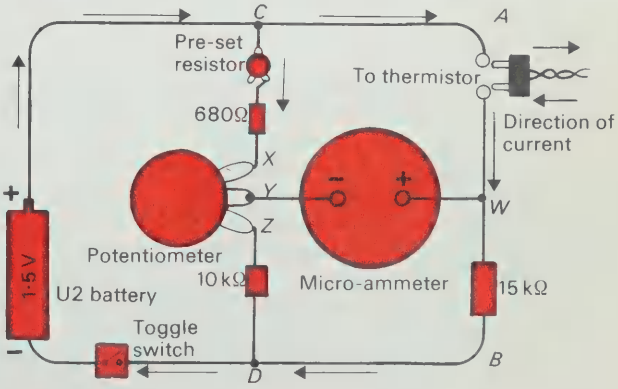


The control unit *

Designs for this unit, based on the principle of the Wheatstone bridge, are well known. (See Nuffield O-Level *Biology, Teachers' Guide* III, pages 46–48.)

The photographs and diagram on this page show the control box and the way in which the components have been connected into the circuit it contains.

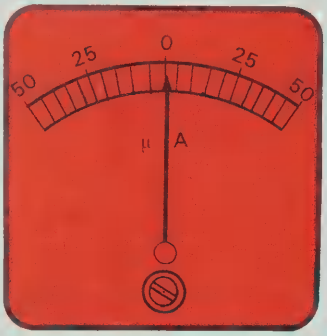




**The unit considered here was designed by Mr David Mansfield, Head of the Chemistry Department of Harvey Grammar School, Folkestone, and permission to use it is acknowledged together with the work of Mr A. W. J. Edwards (formerly Kent Education Committee Inspector) on its construction.*

Explanation for the teacher

In this circuit the micro-ammeter and the wires connected to it form a bridge between the points *W* and *Y* situated on the branches *AB* and *CD*. Here the micro-ammeter is used for detecting, not measuring, any current that may flow across the bridge. The zero is in the centre of the instrument's scale.



When a current flows through this meter the needle will be deflected to the right or left of the zero, depending on the direction in which the current flows.

When the potentials (voltages) of the points *W* and *Y* are the same, no current flows across the bridge arm, so the needle is not deflected from zero. Then, we say that the bridge is balanced.

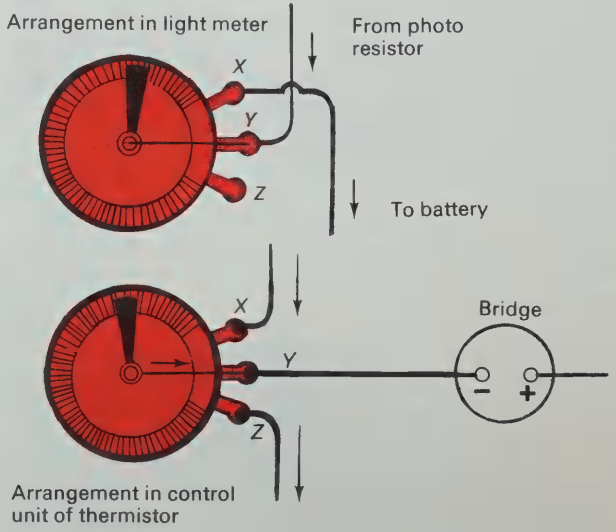
Now we must consider a situation in which the potential at *W* increases or decreases. When the current is switched on, it will flow round the circuit, including the branch *AB*. In passing through the two resistors (thermistor and 15 kΩ fixed resistor) wired into that branch, it will cause a decrease in potential (voltage drop) equal to the applied voltage (1·5). Since at all times this drop in voltage is equally distributed along these two resistors, it is interesting to see what happens as changes in temperature affecting the thermistor cause its resistance to change.

If, for example, we assume that the thermistor at room temperature has a resistance of 3 kΩ, and that the resistance in series with it is 15 kΩ, then $\frac{3}{18}$, or one-sixth, of the applied voltage is dropped in the thermistor. *W* then has a potential of five-sixths of the applied voltage. If the temperature of the thermistor is then raised to body temperature, causing its resistance to drop to, say, 1 kΩ, then the voltage drop across the thermistor would be only $\frac{1}{16}$ of the applied voltage, and the potential of *W* higher than before (namely $\frac{15}{16}$ of the applied voltage).

If the bridge were originally balanced, this change would probably result in the potential of *W* being above that of *Y* at the other end of the bridge arm, causing a current to flow from *W* to *Y* through the meter, which then gives a positive reading (needle to the right of zero). Then, to balance the bridge again, it will be necessary to make an adjustment that raises the potential of point *Y* to that of *W*.

In order to understand how this can be done, we must consider what can happen as the current flows along the branch *CD*. Again we can expect the voltage to decrease gradually due to the resistance offered by the four resistors through which the current must flow. But in the course of this journey, the current, having reduced some of the applied voltage while passing through the first two resistors, reaches the potentiometer. This component is connected to the branch *CD* by its first and third terminals *X* and *Z*.

Compare this use of the potentiometer with that in the light-meter on page 42.

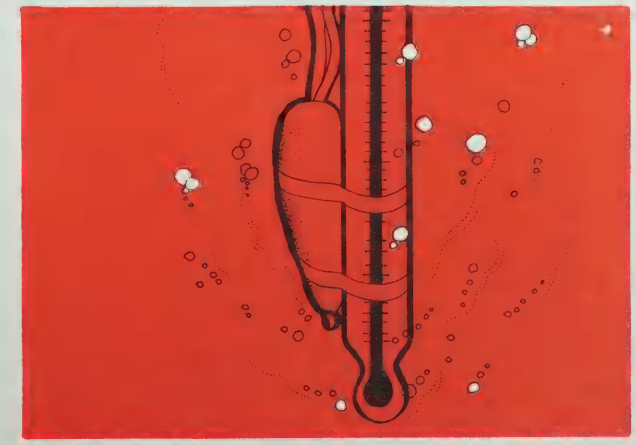


The ends of the coil of resistance wire in the potentiometer are brought out to *X* and *Z*. We can therefore expect the

current to flow from *X* through the potentiometer coil to *Z* and to lower the potential as it goes along. If the pointer knob controlling the wiper arm is rotated, the contact on the arm's free end will therefore be connected to different potentials as it moves over the coil. The potential picked up will be somewhere between its upper value at *X* and its lower value at *Z*. Since the other end of the wiper arm is connected to the middle terminal of the potentiometer and this joins the bridge arm at *Y*, the potential tapped off from the coil by the wiper arm will be passed on to the point *Y*. If this brings the potential of *Y* above that at *W*, current will flow across the bridge from *Y* to *W* and the needle of the micro-ammeter will be deflected to the left, thus giving a negative reading. However, the aim is to keep the bridge balanced, so when the temperature of the thermistor's surroundings causes it to respond in a way that gives a high value to *W*, and a positive reading on the meter, the potential of *Y* must be increased by turning the knob controlling the wiper arm of the potentiometer in an anti-clockwise direction to bring the wiper contact against a point on the coil nearer to *X*. When this action has zeroed the needle of the meter, the current can be switched off and the position of the pointer knob on the protractor scale noted.

The actual temperatures to which readings on the protractor correspond can be read from a conversion graph if the instrument is calibrated in the following way.

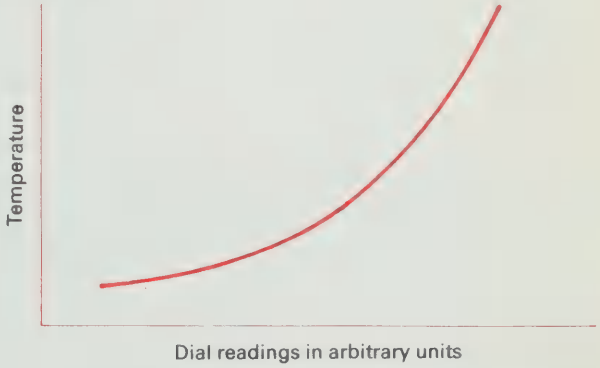
Strap the thermistor against the bulb of a mercury thermometer as shown in the diagram.



Switch on the electric current. Place the thermistor and the thermometer in a bowl of water. Allow time for the thermistor to come into equilibrium with its surroundings. Zero the micro-ammeter and record the reading on the protractor scale.

Repeat, using water of different temperatures between just above freezing point and just below body temperature.

Plot the protractor scale readings against the temperatures of the water.



The values of the fixed resistors (15kΩ, 10kΩ and 680 Ω) have been selected to give an instrument covering the range of temperatures children are most likely to meet when investigating outdoor conditions. If the instrument was set up to deal with a much wider range of temperatures, the children would find themselves limited to such a small part of the protractor that changes in the position of the pointer knob would become practically impossible to determine.

Occasionally children may wish to deal with a temperature beyond the range that the control unit has been set up to cover. When this happens the range of the instrument can be shifted by changing the setting of the pre-set resistor. This is done by inserting a small wooden peg in a slot in its centre and turning slightly in the direction required to extend the range upward or downward.

A new conversion graph must be made each time this is done.

Children using a thermistor
Again the method of doing this is easy to carry out.

Place the thermistor in the situation where the temperature reading is required and the control box in a position where it can easily be manipulated and read.

Connect the thermistor to the control unit. After allowing sufficient time for the thermistor to reach a state of equilibrium with its surroundings, switch on the current and then turn the control knob of the potentiometer in the direction that brings the micro-ammeter needle to zero. When the needle appears to be steady at zero, check if this really is the case by switching off the current temporarily. If the needle still remains steadily on zero, the bridge is balanced.

Record the reading against which the pointer knob has settled on the protractor scale. Use a conversion graph to convert this reading to an actual temperature.

Note that the plug connecting the thermistor to the control unit should not be pulled from its socket before the current is switched off. The micro-ammeter will be damaged if this precaution is ignored.

This equipment can be used for finding out more about temperatures inside animal burrows, hollow trees, compost heaps, lower levels in ponds, and soil below ground level.

A transparent back to the control box may arouse children's interest in the various components it contains, a useful step towards later understanding of this instrument.

Children using a thermistor for investigating the temperature of their school pond

4 Environmental factors: investigations of land and water

Ways in which children can be encouraged to search for evidence of the moving and mixing processes which continually create different types of rock and soil and arrange them in different shapes and patterns have already been considered (see Volume 2 Part 2, pages 58–61). But again, each discovery leads to further questions:

Are these differences great or small?
Do they affect the water filling hollows in the land or moving over its surface?

The search for information to match against earlier discoveries and those still to be made continues.

General observations about the shape and surface of the land can be recorded on landscape sketches. See Volume 2 Part 2, page 47, for a method of producing these sketches.

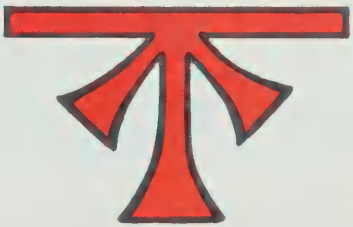
The height of the land

In England the common base line to which heights and depths of contour lines and bench marks are related is sea level, ie mean high water mark at Newlyn. The height of any place on land above sea level can be estimated if its position in relation to the two measured heights or contour lines between which it is situated, is noted.

The 1:10 000 (6 inches to 1 mile) Ordnance Survey maps are useful for this purpose as the contours on them are clearly visible.

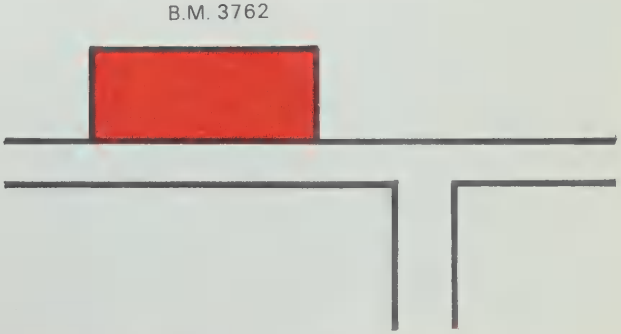
See Volume 4, for information about the changes in scales and height measurements on maps as a result of metrication.

Bench marks
Sometimes children may find bench marks in places they explore. These marks, cut deeply into stone or brick on any permanent structure, were placed all over the country by the Ordnance Survey.



The bar on the sign is at a certain height above sea level.

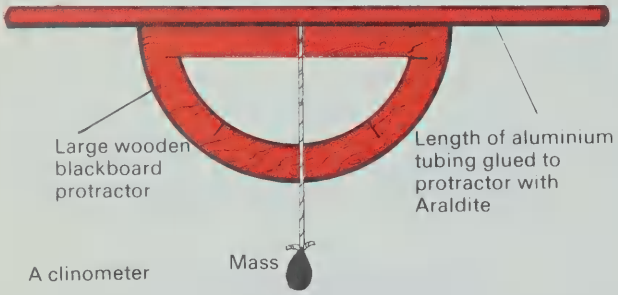
On the old 6 inches to 1 mile Ordnance Survey maps bench marks are shown in the following way.



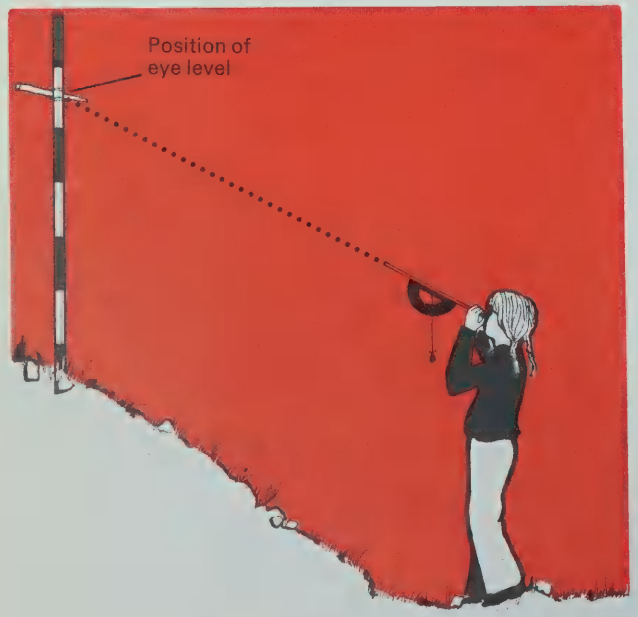
The figures give the number of feet above sea level at which the bar on the sign has been placed.

How steep is the slope?

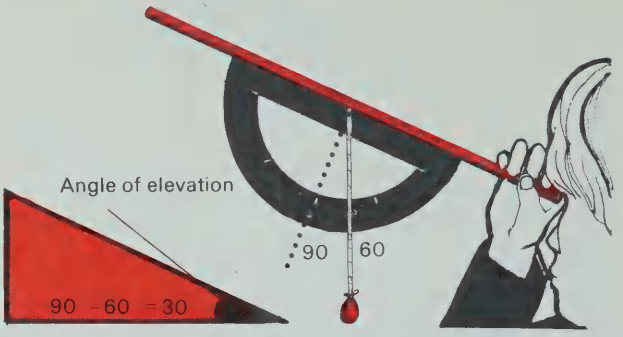
Slopes can be compared by using a clinometer to find their angles of elevation. The steeper the slope the larger the angle of elevation.



Plant a surveyor's ranging rod at the top of the slope. Mark a point on the rod at the same height from the ground as the observer's eye. From the bottom of the slope sight this point through the aluminium tube of the clinometer.

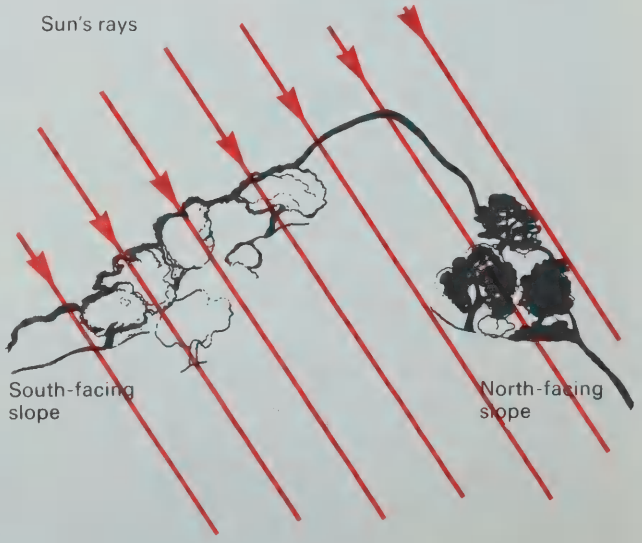


The angle made by the weighted thread with 90° while doing this is equal to the angle of elevation of the slope.



The aspect of the land

Does the slope face the sun at 12 noon ?



On which slope are the sun's rays more concentrated ?

What effect will this have on the temperature of the soil ?

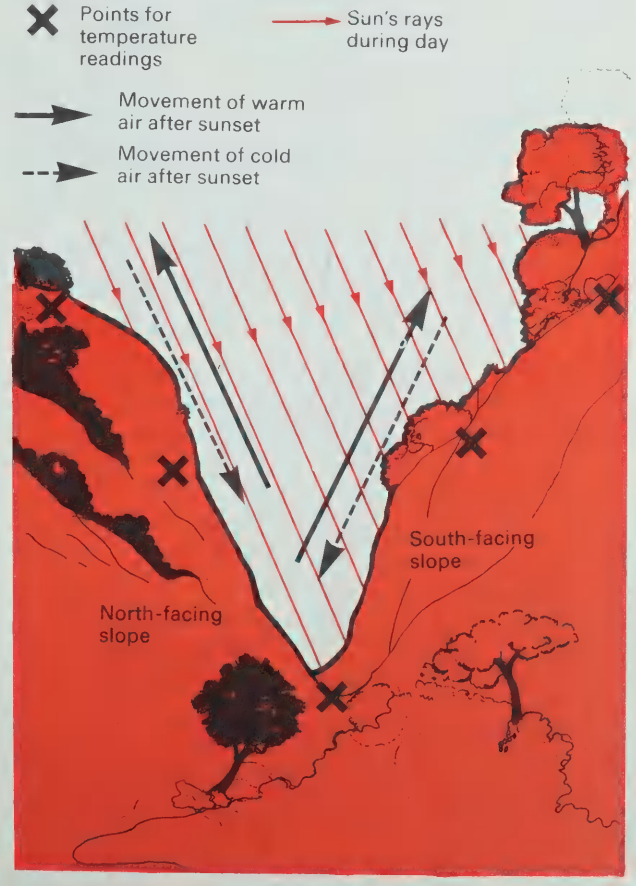
On which slope will we find the largest shadows ?

Why do we sometimes find early morning fog at the bottom of the valley when the hillsides are clear ?

Why do we get spring frost in the valley and none on the higher slopes ?

Where is the best position for a house, an orchard ? On the valley floor, 60 m up the north-facing slope, or 60 m up the south-facing slope ?

Such a question could be tackled by children spending some time in a residential field centre near a valley if they took the temperature readings at ground level at the different places mentioned above at 09.00, 12.00, 15.00, 18.00 and 21.00 hours each day.


Points for temperature readings
Sun's rays during day
Movement of warm air after sunset
Movement of cold air after sunset
South-facing slope
North-facing slope

The rocks

Sometimes rocks may form a conspicuous feature of a study area, for example :

Outcrops in limestone grassland.

Rock faces exposed in a quarry or cliff face.
A rocky seashore.
Broken particles forming spoil heaps or screes.

When children's attention is attracted by such features they may begin to speculate. One obvious feature they might consider is the amount of shade cast by particular

rocks. Would this mean that some parts of a rock pool, for example, receive more light than others? Does there seem to be any relationship between this and the positions of living things in the pool?

It might be interesting to keep a record of the areas of shadow cast by the rock at, say, two-hourly intervals during a day.

Then there is the rock itself. Is it hard or soft? In what sort of rock can the most cracks and crevices be found? Do more seeds come to rest and more animals take shelter in places where there are plenty of cracks between the rocks? Are there any plants in the district growing out of rocky cracks?

By this time children probably know many ways of testing and comparing different rocks through their earlier experience of investigating and comparing collections of materials (see Volume 2 Part 1, page 68).

Hardness

If children have already devised their own crude scale for comparing the hardness of rocks, they might now adopt the scale generally used by geologists, called Moh's scale. Observers in different places can exchange information by using this common scale.

Moh's scale of hardness

The numbers given to the ten minerals below are related to their increasing hardness:

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Felspar
7. Quartz
8. Topaz
9. Corundum
10. Diamond

With the exception of no. 1, pieces of each of these rocks will score marks that cannot be erased on those lower on the scale but will not be permanent on those rocks corresponding to higher numbers.

Griffin and George supply a set of pencils for testing hardness according to this scale (see their *Field Studies* catalogue no. L08–670, page 44). The points of the pencils consist of minerals nos. 4–7 on the above scale. Testing is carried out by attempting to scratch unknown rocks with these pencils.

If, for example, no. 4 (fluorite) and no. 5 (apatite) will not permanently mark a certain rock but no. 6 (felspar) will do so, the rock is obviously harder than 5 and not as hard as 6. So it can be rated at approximately 5·5 on the scale.

If a rock softer than no. 4 can be marked with a penny, it will rate 3·5. If a fingernail permanently marks a rock, its rating will be 2·5. Two other useful ratings to remember are 5·5 for rocks that can just be marked by a penknife and 6·5 for those just marked by a steel file.

Minerals in rocks

Any children who have examined rocks with the aid of a good stereomicroscope will probably be well aware that they often consist of a number of different materials known as minerals. When rocks are crushed and mixed with other things they will produce soils containing these minerals.

The task of identifying different minerals in rocks is much too difficult for thirteen-year-olds. However, those with access to a museum containing a good geological collection may like to try to take their investigations a little further.

They should collect different rocks from the site they are studying and then use each of them to make a streak across the unglazed back of a porcelain tile. They should note the colour of the streak; it may not be the same as the rock itself.

In their *Field Studies* catalogue (page 44) Griffin and George have included a key for identification of minerals based on streak and hardness tests. Children may succeed in tracing a few minerals with its help and they could then try to see more of them in a museum. They could also consult books in the reference library to see whether any plants make use of such substances.

The lime test

The presence of lime in rock can often be traced without much difficulty. With a dropper or syringe place a few drops of dilute hydrochloric acid (ten percent) on the rock being examined. Effervescence (fizzing) is an indication of the presence of lime.

When rocks reacting in this way break up they will contribute alkaline material to soils. What plants are indicators of alkaline soils? What animals need lime to produce protective coverings?

Soils

When children begin to wonder whether differences between soils have anything to do with the distribution of living things, the teacher should encourage discussion of the work to be set up. Soils will be disturbed if they are to be brought into school for investigation. The effects of this can be to alter their crumb structure and the amount of air they contain, and interfere with the movement of water through them. As a result they will become different from the material that was in contact with plant roots and subterranean animals. Therefore some of the most useful information about soils in relation to living things is likely to be that discovered by observations and tests carried out in the field.

The validity of the following investigations is not destroyed by moving the soil.

Comparison by feeling

This will soon reveal variations in texture. All samples handled should be slightly moist as well as being comparable with regard to size and method of collection.

Mould the soil in the hand, then rub it between the thumb and index finger.

When doing this children could make use of the following simple key for deciding on the type of soil in which their specimens are living and growing.

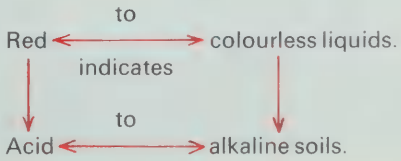
1. Soil feels gritty Soil not gritty	2 4
2. Soil will form a cohesive ball Soil will not form a cohesive ball	Light loam 3
3. Soil stains the fingers Soil does not stain the fingers	Heavy sand Light sand
4. Soil silky or sticky Soil neither silky nor sticky	5 Loam
5. Soil will not polish when rubbed between the fingers Soil will polish when rubbed between the fingers	6 7
6. Soil just slightly silky Soil noticeably silky	Silty loam Light silt
7. Soil very difficult to deform between finger and thumb Soil easily deformed	Clay Heavy loam

Acidity and alkalinity

At an earlier stage children will have discovered that materials can range in their reactions from acid to alkaline (see Volume 2 Part 1, page 80). Now they might make use of a wider range of indicators to compare these properties in soils, for example :

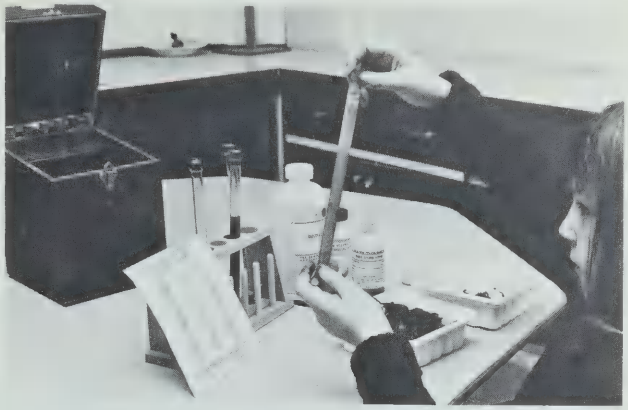
1. Litmus paper (see Volume 2 Part 1, pages 80–81 for method).

2. Four percent potassium salicylate. Shake a small sample of soil with this indicator. Allow soil to settle and then note the colour of the liquid.



A sample of soil taken with a soil corer

3. The British Drug Houses soil indicator. Shake a sample of soil mixed with barium sulphate in a test tube of distilled water to which the BDH indicator has been added according to the directions included with the outfit.



Testing soils for acidity or alkalinity

Barium sulphate ensures that soil settles quickly leaving the colour of the liquid clearly visible. Match this colour against colours on the chart supplied, and the extent to which the soil has made the neutral indicator solution become acid or alkaline can be seen immediately. Colours on the chart correspond to pH figures.

Water and the land

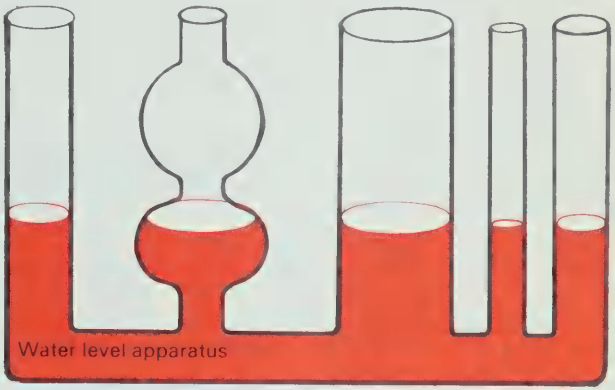
Water in the soil

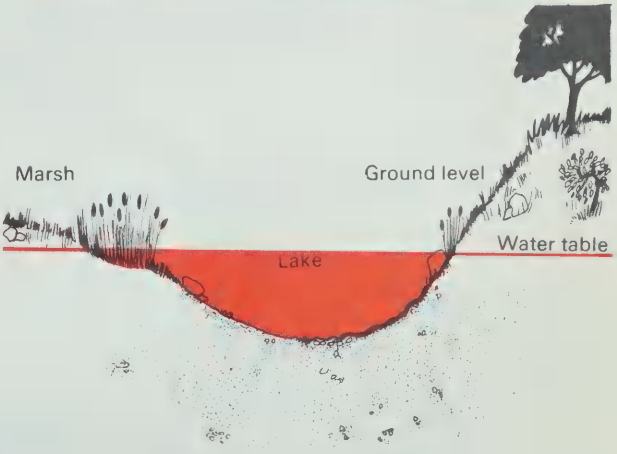
The water content of soil can be affected by conditions such as the slope of the land, the presence or absence of impermeable layers of rock, the amount of humus which readily absorbs and holds water and the size of the soil particles. Soils composed of small particles often become waterlogged.

The less water there is between particles of soil the more space there is for air. In well-aerated soils bacteria can cause the decay of dead things more rapidly and so release nutrient chemicals for plant growth.

The water table

It is useful to know the position of the water table. Since water finds its own level its surface forms a horizontal line. This is the water table. Soils and permeable rocks below this line will be permanently saturated with water and therefore will have no spaces left for air.





Lakes, rivers, bogs indicate that the water table is above ground level.
Marshes indicate that the water table is at ground level.
A high water table is one that is near ground level.
A low water table is one that is well below ground level.

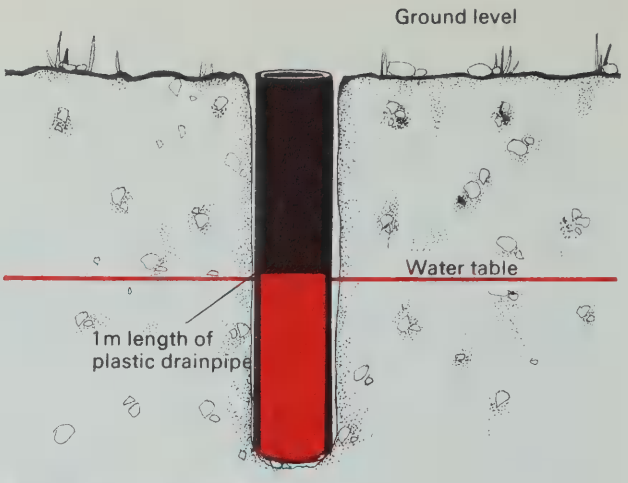
Very heavy rainfall or drought can cause temporary rises and falls in the water table but these events will not have as much effect on living things as the prevailing conditions.

To find the position of the water table :

1. Look out for outlets to drainpipes in walls or outfalls from sewers. The water table would only drop below this level in very dry weather. Drainage should prevent water from rising above the level of these pipes.

2. Dig a hole where you think that the water table is fairly near ground level and sink a 1-m length of plastic drainpipe in it. Measure the distance between the surface of water that collects in the hole and ground level. This should not be done during extremes of dry or wet weather.

For investigations to discover the amount of air in an undisturbed soil sample and the amount of water it contains that is freely available to plants, refer to Volume 2 Part 2, page 53.



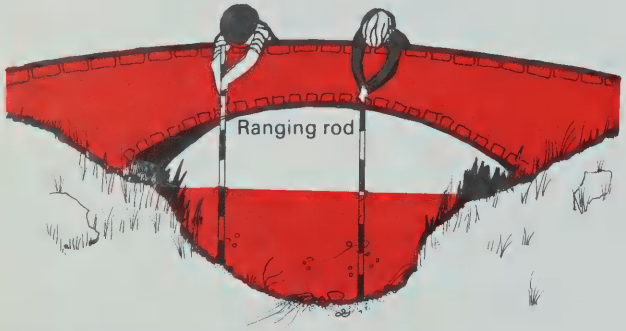
Water above ground level

Depth

These measurements may be made from a low bridge or a boat if wading is impossible. Great care must be taken to see that children working on this are in no danger.

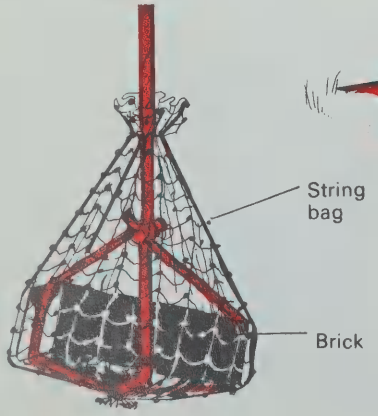
For depths of less than 2 m, measure the part of a surveyor's ranging rod submerged at different observation points.

For depths greater than 2 m, attach a brick enclosed in a string bag to a rope marked in half-metres. Lower the brick until it rests on the bottom of the water being measured. Keep the rope taut and measure the part that becomes wet.



Where is the deepest part of the stream?

Measuring the depth of water in a river



Rate of flow

To compare water's rate of flow at the surface observe the time a floating object takes to cover a convenient distance when placed in the middle and near different sides of a stream or river. The objects used should be just visible above the surface of the water. Very light objects are easily deflected by wind. You might use a rubber ball, a piece of wood or a corked bottle partly filled with water.

If you want to compare the rate of flow at lower depths, arbitrary measurements can be made with a flowmeter based on the idea of the da Vinci apparatus for measuring wind strength (see Volume 2 Part 2, page 11). This will work in clear water.

In the home-made device illustrated in the photograph above, the freely swinging metal sheet and the arbitrary scale are attached to a pole by plastic-covered Terry clips, so that their positions can be adjusted in relation to the depth at which measurements are required.

Water on the seashore

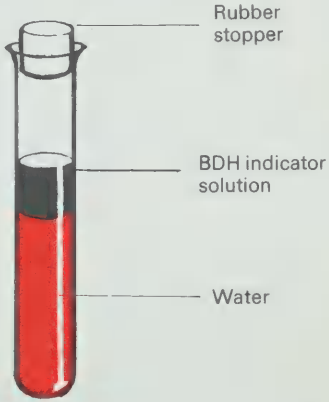
Movement up and down the seashore

Tides by their nature create different living conditions for plants and animals at various levels on the seashore.

Information can be collected by children working from schools or residential centres with easy access to a seashore about the length of time selected points on the beach are not covered by water (see page 31). Mark these points by placing pegs at regular intervals such as 5 m from the top of the beach to the level of low water spring tides (LWST).

The acidity or alkalinity of sea water

Add the British Drug Houses indicator to some sea water in the proportions indicated by marks on the test tubes supplied with the BDH soil-testing outfit. Shake well and match the colour obtained against the BDH colour chart.



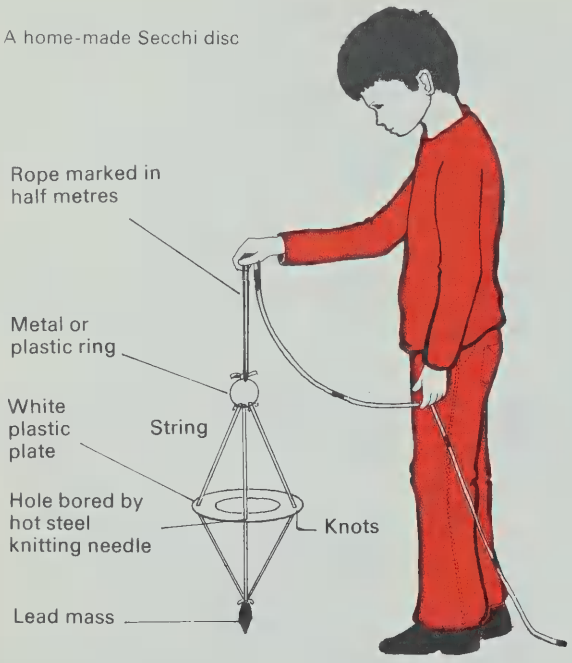
Solid material suspended in sea or river water

Rough estimates of the quantities of solid material can be made by filtering similar quantities of water collected from different places and then comparing the amount of sediment on the filter papers when they have been dried.

If there is much material or plankton in suspension, the water will be turbid and prevent light reaching the plants and creatures at lower depths.

The extent to which this happens can be investigated by means of a home-made 'Secchi disc', constructed as shown in the next diagram.

Lower this from a bridge or boat into the water until it becomes invisible. The clearer the water, the longer this will take, so the length of rope used in different places can be compared.



A home-made Secchi disc

Pollution

A useful arbitrary scale for estimating the extent to which water is polluted is based on the presence or absence of certain aquatic creatures since some of these can stand more contact with harmful substances than others.

Level of pollution	Symbol for records	Animals serving as indicators
Very low	A	Stone fly nymphs May fly nymphs
Low	B	Caddis larvae Fresh-water shrimps
High	C	Water slaters (*Asellus*) Chironimid larvae
Very high	D	Rat-tailed maggot (*Eristalis* larva)
	E	No animal life

A pollution study kit used in the ACE/*Sunday Times* water pollution survey can be obtained from :

The Advisory Centre for Education
32 Trumpington Street
Cambridge (Tel. Cambridge 51456).

5 Environmental factors: investigations of conditions due to living things

The influence exerted by the presence or activities of certain plants and animals, including man, on the living conditions of other organisms is not easy to measure. However, children can carry out many investigations that provide evidence of the effectiveness of such influence.

Here are some suggestions.

Comparisons

Shall we find different species and quantities of living things on parts of the same place exposed to varying influences?

Use the 'presence and absence' method of sampling described on page 21 to compare the frequency of selected living things on plots of similar size, exposed to different influences. Children will probably find it better to deal with plants and animals separately.

Make comparisons such as those suggested in the table on the right from sample plots of similar sizes.

Plots for comparison	Biotic influence
Ground around a farm gate and from the middle of the field	Trampling by cattle
Chalk grassland used for pasturing sheep and chalk scrub with no sheep	Sheep grazing
Burnt and unburnt heathland	Fires started by careless people
Ground beneath trees and from woodland clearings	Shade from trees
Cants in managed woodland in which sweet chestnut trees are coppiced in different years	Forestry practice
Ground in marshy and drained parts of a meadow	Agricultural work
Mown and unmown grassland in a garden or park	Work of gardeners
Hoed and neglected flower-beds in the same garden	
Areas of the same lawn treated and left free from weed-killer	

Can gardeners and farmers improve the growth of plants?

Compare the growth of similar numbers of the same species of plants :

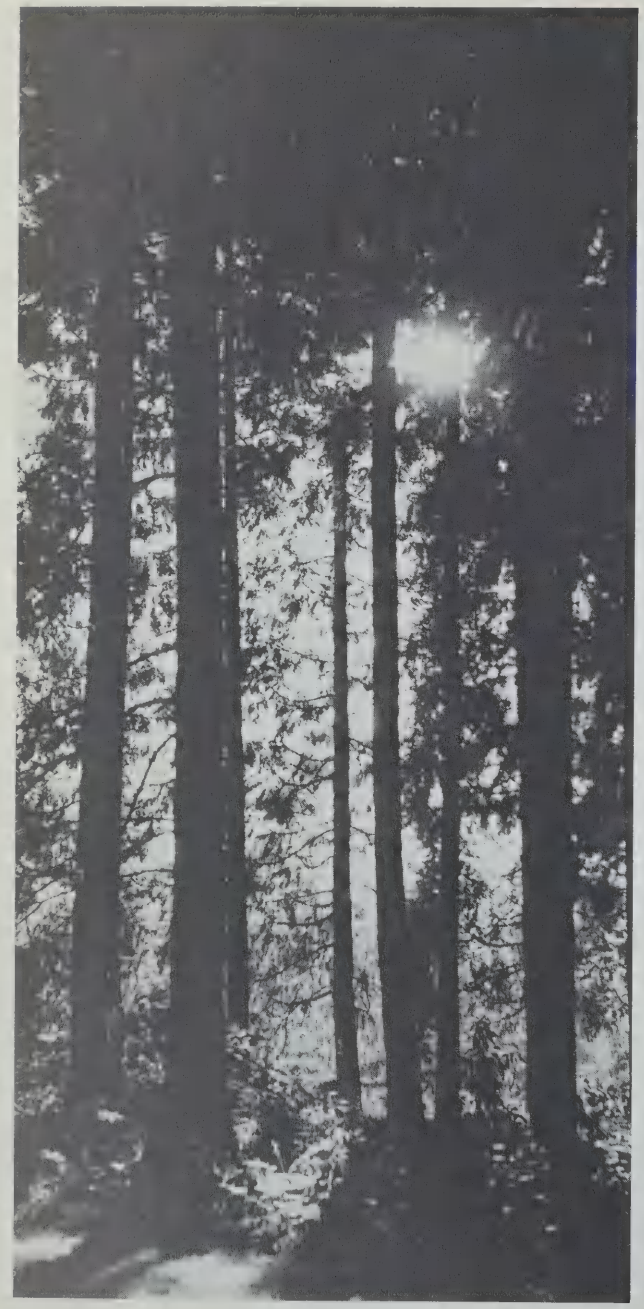
1. In heavy clay soils with and without the addition of lime.

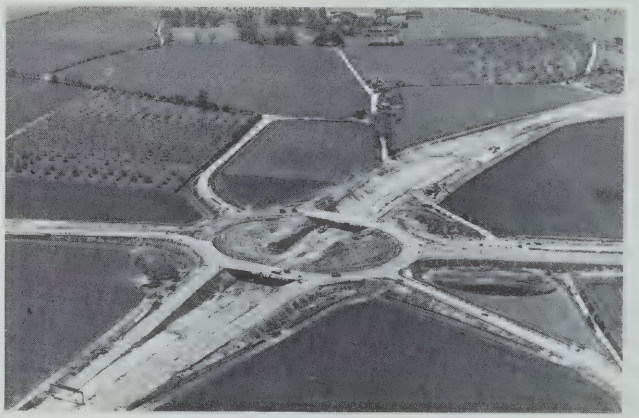
2. In the same type of soil with and without the addition of fertiliser.

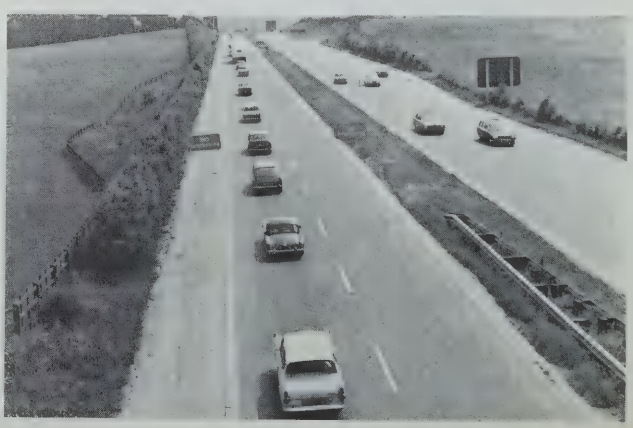
3. Protected from and exposed to cold (straw, glass or polythene sheeting can be used for protection).

For this work use small bedding plants or cabbages ready for planting out.

Select plants of the same size. Make sure that the conditions in which the experimental and control plants grow are similar.







Studies of man-made developments: individual and group projects

1. Make a list of any man-made developments in your neighbourhood that in your opinion provide better living conditions (habitats) for plants and animals.

Here are some examples :

Grass banking on motorways is inaccessible to the public so wild flowers can flourish there without disturbance.

Hedgerows provide shelter and nesting sites for birds, and support for climbing plants.

Reservoirs are often used by migrating birds as resting places.

Who is responsible for the establishment of such places in the districts you can investigate ?

What are some of the most interesting plants and animals that can be found in them ?

Is there a danger of any of these places disappearing ? Who could bring this about ?

Some interesting investigations on the disappearance of hedgerows were organised at Monks Wood Experimental Station, Huntingdonshire. Can you find out more about this ?

2. Individual and group projects.

a. The action of earthworms :
How do these animals affect the soil ?
Can you find ways of repeating some of the investigations Charles Darwin described in his book *Vegetable Mould and Earthworms* (John Murray, 1882).

b. Animals as agents of dispersal of fruits and seeds (see Volume 3 Part 1, pages 56, 58 and 59). Has the growth of world travel aided this process ?

c. Causes of decay. See Volume 2 Part 2, pages 56–57, for directions for making compost. How is this process helped by fungi, bacteria and insects ?

Resources for learning

When children become interested in ways in which living things can affect environmental conditions they will soon find out that man, through his ability to invent and use machines, can change his surroundings and create new environmental conditions and problems more rapidly and effectively than any other living thing.

His activities can work both ways. When he drains his land he certainly destroys habitats and their inhabitants, but at the same time he creates different living and growing conditions and clears the way for plants and animals that previously could not compete with existing populations. His work may help to increase our food supplies.

This is only one illustration of the need for knowledge of living things in relation to their surroundings when changes have to be planned.

Field studies will bring children in contact with many problems concerning human influences on the environment. When they want to think more deeply about these matters, secondary sources of information can supplement their own first-hand experience by giving them knowledge of places beyond their own country, ideas for discussion and suggestions for further local investigations.

The school library must therefore be developed to include a bank of multi-media resources relating to the environment. Teachers who are considering providing this aid to learning will find much useful information in DELTA (Directory of Environmental Literature and Teaching Aids). This is a publication compiled and kept up to date for the Council of Environmental Education and it can be obtained from :

The School of Education
University of Reading
24 London Road
Reading RG1 5LQ.
Berkshire

It provides critical appraisals of books, films, film strips and slides, posters, study kits, games, work cards and magazines dealing with the following topics.

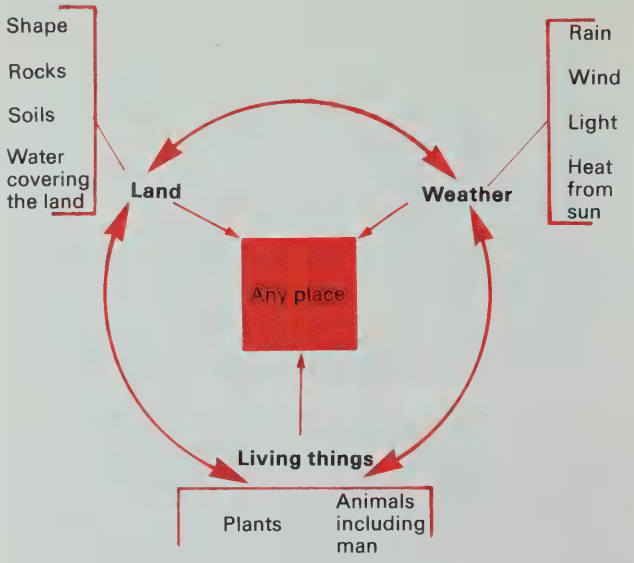
Settlements and villages
Rural land use
Forestry
Population growth
Town growth
Housing problems
Transport and communication
Food and water supplies
Crop rotation
Prevention of soil erosion
Refuse and sewage disposal
Noise
Problems of increasing leisure
Problems created by taking materials from the earth (quarrying, mining, etc)
Pollution (land, water and air)
Effects on wild life and human beings of spraying with insecticides
Disasters and their effect on wild life (*Torrey Canyon* wreck)
Animals in danger of extinction (World Wild Life Movement)
Protection and conservation of bird life
Reclamation of derelict land (eg the Lower Swansea Valley project)
National parks

A collection of maps showing land use at different periods is a useful starter for discussions on urban spread.

A conception of environment

Over and over again the search for evidence of relationships between plants and animals and their living conditions will bring children in contact with the idea of environment. As this is one of the major concepts of biology perhaps we should think more carefully about its meaning.

Here is an attempt to do so with the help of a diagram.



This suggests that an understanding of environment involves the ability to think of many variable conditions, all in operation at the same time, continually affecting and modifying places, their inhabitants and each other.

It is only through a great deal of experience that such a complex idea can be grasped, so for children of thirteen, any depth of understanding must lie some years ahead. Nevertheless, they can certainly begin gathering the experience on which this future understanding must be based.

Their attempts to discover relationships can help them to become aware of how many things are happening at the same time in their surroundings, and curiosity about the effects of this can become one of the greatest incentives to further exploration.

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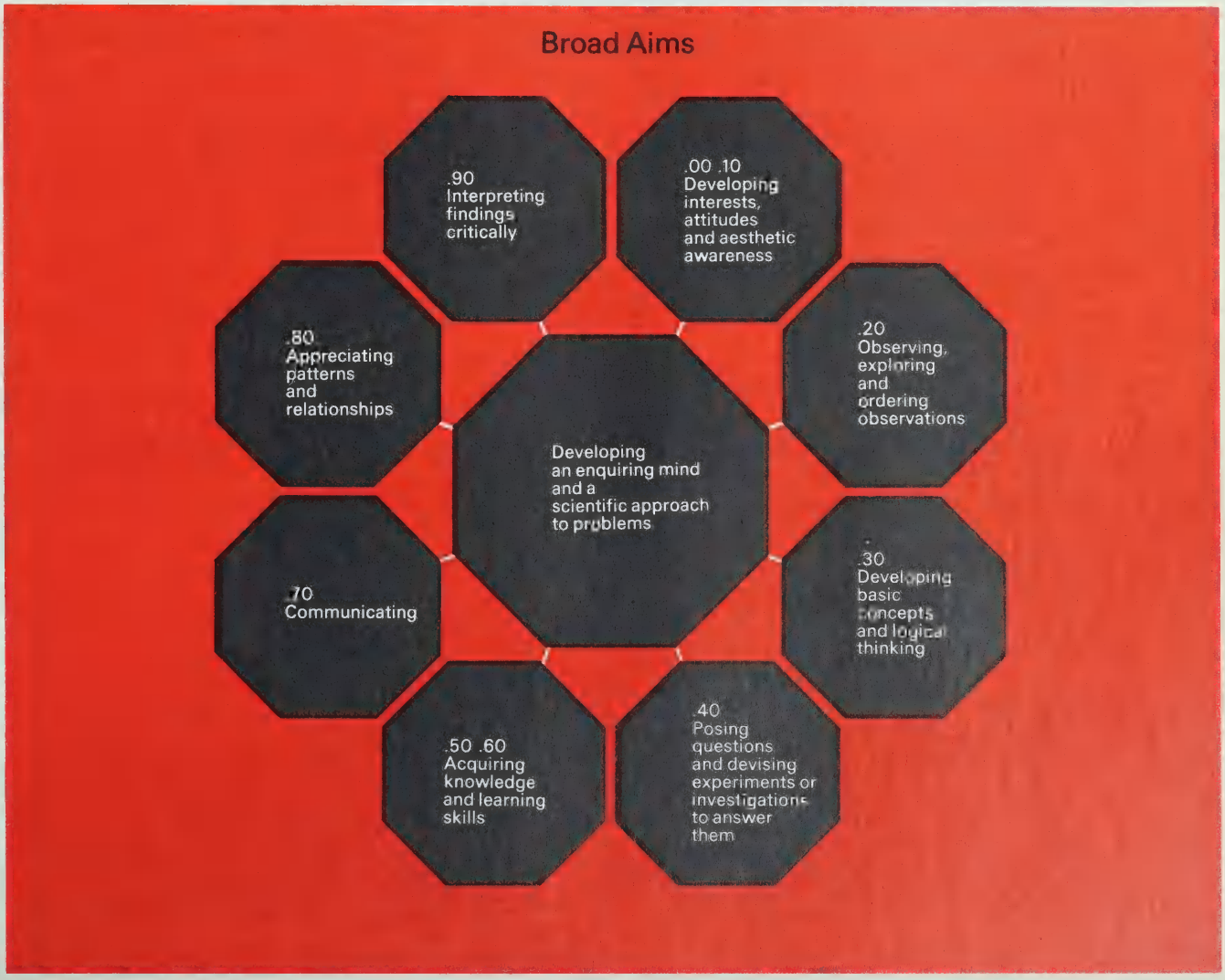
Objectives for children learning science

Guide lines to keep in mind


Broad Aims
.90 Interpreting findings critically
.00 .10 Developing interests, attitudes and aesthetic awareness
.80 Appreciating patterns and relationships
.20 Observing, exploring and ordering observations
Developing an enquiring mind and a scientific approach to problems
.70 Communicating
.30 Developing basic concepts and logical thinking
.50 .60 Acquiring knowledge and learning skills
.40 Posing questions and devising experiments or investigations to answer them

What we mean by Stage 1, Stage 2 and Stage 3

Attitudes, interests and aesthetic awareness

.00/.10

Stage 1
Transition from intuition to concrete operations. Infants generally.

The characteristics of thought among infant children differ in important respects from those of children over the age of about seven years. Infant thought has been described as 'intuitive' by Piaget; it is closely associated with physical action and is dominated by immediate observation. Generally, the infant is not able to think about or imagine the consequences of an action unless he has actually carried it out, nor is he yet likely to draw logical conclusions from his experiences. At this early stage the objectives are those concerned with active exploration of the immediate environment and the development of ability to discuss and communicate effectively: they relate to the kind of activities that are appropriate to these very young children, and which form an introduction to ways of exploring and of ordering observations.

1.01 Willingness to ask questions
1.02 Willingness to handle both living and non-living material.
1.03 Sensitivity to the need for giving proper care to living things.
1.04 Enjoyment in using all the senses for exploring and discriminating.
1.05 Willingness to collect material for observation or investigation.

Concrete operations. Early stage.

In this Stage, children are developing the ability to manipulate things mentally. At first this ability is limited to objects and materials that can be manipulated concretely, and even then only in a restricted way. The objectives here are concerned with developing these mental operations through exploration of concrete objects and materials—that is to say, objects and materials which, as physical things, have meaning for the child. Since older children, and even adults prefer an introduction to new ideas and problems through concrete example and physical exploration, these objectives are suitable for all children, whatever their age, who are being introduced to certain science activities for the first time.

1.06 Desire to find out things for oneself.
1.07 Willing participation in group work.
1.08 Willing compliance with safety regulations in handling tools and equipment.
1.09 Appreciation of the need to learn the meaning of new words and to use them correctly.

Stage 2
Concrete operations. Later stage.

In this Stage, a continuation of what Piaget calls the stage of concrete operations, the mental manipulations are becoming more varied and powerful. The developing ability to handle variables—for example, in dealing with multiple classification—means that problems can be solved in more ordered and quantitative ways than was previously possible. The objectives begin to be more specific to the exploration of the scientific aspects of the environment rather than to general experience, as previously. These objectives are developments of those of Stage 1 and depend on them for a foundation. They are those thought of as being appropriate for all children who have progressed from Stage 1 and not merely for nine- to eleven-year-olds.

2.01 Willingness to co-operate with others in science activities.
2.02 Willingness to observe objectively.
2.03 Appreciation of the reasons for safety regulations.
2.04 Enjoyment in examining ambiguity in the use of words.
2.05 Interest in choosing suitable means of expressing results and observations.
2.06 Willingness to assume responsibility for the proper care of living things.
2.07 Willingness to examine critically the results of their own and others' work.
2.08 Preference for putting ideas to test before accepting or rejecting them.
2.09 Appreciation that approximate methods of comparison may be more appropriate than careful measurements.

Stage 3
Transition to stage of abstract thinking.

This is the Stage in which, for some children, the ability to think about abstractions is developing. When this development is complete their thought is capable of dealing with the possible and hypothetical, and is not tied to the concrete and to the here and now. It may take place between eleven and thirteen for some able children, for some children it may happen later, and for others it may never occur. The objectives of this stage are ones which involve development of ability to use hypothetical reasoning and to separate and combine variables in a systematic way. They are appropriate to those who have achieved most of the Stage 2 objectives and who now show signs of ability to manipulate mentally ideas and propositions.

3.01 Acceptance of responsibility for their own and others' safety in experiments.
3.02 Preference for using words correctly.
3.03 Commitment to the idea of physical cause and effect.
3.04 Recognition of the need to standardise measurements.
3.05 Willingness to examine evidence critically.
3.06 Willingness to consider beforehand the usefulness of the results from a possible experiment.
3.07 Preference for choosing the most appropriate means of expressing results or observations.
3.08 Recognition of the need to acquire new skills.
3.09 Willingness to consider the role of science in everyday life.

Attitudes, interests and aesthetic awareness

.00/.10

1.11 Awareness that there are various ways of testing out ideas and making observations.
1.12 Interest in comparing and classifying living or non-living things.
1.13 Enjoyment in comparing measurements with estimates.
1.14 Awareness that there are various ways of expressing results and observations.
1.15 Willingness to wait and to keep records in order to observe change in things.
1.16 Enjoyment in exploring the variety of living things in the environment.
1.17 Interest in discussing and comparing the aesthetic qualities of materials.

2.11 Enjoyment in developing methods for solving problems or testing ideas.
2.12 Appreciation of the part that aesthetic qualities of materials play in determining their use.
2.13 Interest in the way discoveries were made in the past.

3.11 Appreciation of the main principles in the care of living things.
3.12 Willingness to extend methods used in science activities to other fields of experience.

Observing, exploring and ordering observations

.20

1.21 Appreciation of the variety of living things and materials in the environment.
1.22 Awareness of changes which take place as time passes.
1.23 Recognition of common shapes—square, circle, triangle.
1.24 Recognition of regularity in patterns.
1.25 Ability to group things consistently according to chosen or given criteria.

1.26 Awareness of the structure and form of living things.
1.27 Awareness of change of living things and non-living materials.
1.28 Recognition of the action of force
1.29 Ability to group living and non-living things by observable attributes.
1.29a Ability to distinguish regularity in events and motion.

2.21 Awareness of internal structure in living and non-living things.
2.22 Ability to construct and use keys for identification.
2.23 Recognition of similar and congruent shapes.
2.24 Awareness of symmetry in shapes and structures.
2.25 Ability to classify living things and non-living materials in different ways.
2.26 Ability to visualise objects from different angles and the shape of cross-sections.

3.21 Appreciation that classification criteria are arbitrary.
3.22 Ability to distinguish observations which are relevant to the solution of a problem from those which are not.
3.23 Ability to estimate the order of magnitude of physical quantities.

	Developing basic concepts and logical thinking .30	Posing questions and devising experiments or investigations to answer them .40
Stage 1 Transition from intuition to concrete operations. Infants generally.	*1.31* Awareness of the meaning of words which describe various types of quantity. *1.32* Appreciation that things which are different may have features in common.	*1.41* Ability to find answers to simple problems by investigation. *1.42* Ability to make comparisons in terms of one property or variable.
Concrete operations. Early stage.	*1.33* Ability to predict the effect of certain changes through observation of similar changes. *1.34* Formation of the notions of the horizontal and the vertical. *1.35* Development of concepts of conservation of length and substance. *1.36* Awareness of the meaning of speed and of its relation to distance covered.	*1.43* Appreciation of the need for measurement. *1.44* Awareness that more than one variable may be involved in a particular change.
Stage 2 Concrete operations. Later stage.	*2.31* Appreciation of measurement as division into regular parts and repeated comparison with a unit. *2.32* Appreciation that comparisons can be made indirectly by use of an intermediary. *2.33* Development of concepts of conservation of weight, area and volume. *2.34* Appreciation of weight as a downward force. *2.35* Understanding of the speed, time, distance relation.	*2.41* Ability to frame questions likely to be answered through investigations. *2.42* Ability to investigate variables and to discover effective ones. *2.43* Appreciation of the need to control variables and use controls in investigations. *2.44* Ability to choose and use either arbitrary or standard units of measurement as appropriate. *2.45* Ability to select a suitable degree of approximation and work to it. *2.46* Ability to use representational models for investigating problems or relationships.
Stage 3 Transition to stage of abstract thinking.	*3.31* Familiarity with relationships involving velocity, distance, time, acceleration. *3.32* Ability to separate, exclude or combine variables in approaching problems. *3.33* Ability to formulate hypotheses not dependent upon direct observation. *3.34* Ability to extend reasoning beyond the actual to the possible. *3.35* Ability to distinguish ■ logically sound proof from others less sound.	*3.41* Attempting to identify the essential steps in approaching a problem scientifically. *3.42* Ability to design experiments with effective controls for testing hypotheses. *3.43* Ability to visualise a hypothetical situation as a useful simplification of actual observations. *3.44* Ability to construct scale models for investigation and to appreciate implications of changing the scale.

Acquiring knowledge and learning skills

.50/.60

1.51 Ability to discriminate between different materials.
1.52 Awareness of the characteristics of living things.
1.53 Awareness of properties which materials can have.
1.54 Ability to use displayed reference material for identifying living and non-living things.

1.55 Familiarity with sources of sound.
1.56 Awareness of sources of heat, light and electricity.
1.57 Knowledge that change can be produced in common substances.
1.58 Appreciation that ability to move or cause movement requires energy.
1.59 Knowledge of differences in properties between and within common groups of materials.

1.61 Appreciation of man's use of other living things and their products.
1.62 Awareness that man's way of life has changed through the ages.
1.63 Skill in manipulating tools and materials.
1.64 Development of techniques for handling living things correctly.
1.65 Ability to use books for supplementing ideas or information.

2.51 Knowledge of conditions which promote changes in living things and non-living materials.
2.52 Familiarity with a wide range of forces and of ways in which they can be changed.
2.53 Knowledge of sources and simple properties of common forms of energy.
2.54 Knowledge of the origins of common materials.
2.55 Awareness of some discoveries and inventions by famous scientists.
2.56 Knowledge of ways to investigate and measure properties of living things and non-living materials.
2.57 Awareness of changes in the design of measuring instruments and tools during man's history.
2.58 Skill in devising and constructing simple apparatus.
2.59 Ability to select relevant information from books or other reference material.

3.51 Knowledge that chemical change results from interaction.
3.52 Knowledge that energy can be stored and converted in various ways.
3.53 Awareness of the universal nature of gravity.
3.54 Knowledge of the main constituents and variations in the composition of soil and of the earth.
3.55 Knowledge that properties of matter can be explained by reference to its particulate nature.
3.56 Knowledge of certain properties of heat, light, sound, electrical, mechanical and chemical energy.
3.57 Knowledge of a wide range of living organisms.
3.58 Development of the concept of an internal environment.
3.59 Knowledge of the nature and variations in basic life processes.

3.61 Appreciation of levels of organisation in living things.
3.62 Appreciation of the significance of the work and ideas of some famous scientists.
3.63 Ability to apply relevant knowledge without help of contextual cues.
3.64 Ability to use scientific equipment and instruments for extending the range of human senses.

	Communicating .70	Appreciating patterns and relationships .80
Stage 1 Transition from intuition to concrete operations. Infants generally.	*1.71* Ability to use new words appropriately. *1.72* Ability to record events in their sequences. *1.73* Ability to discuss and record impressions of living and non-living things in the environment. *1.74* Ability to use representational symbols for recording information on charts or block graphs.	*1.81* Awareness of cause-effect relationships.
Concrete operations. Early stage.	*1.75* Ability to tabulate information and use tables. *1.76* Familiarity with names of living things and non-living materials. *1.77* Ability to record impressions by making models, painting or drawing.	*1.82* Development of a concept of environment. *1.83* Formation of a broad idea of variation in living things. *1.84* Awareness of seasonal changes in living things. *1.85* Awareness of differences in physical conditions between different parts of the Earth.
Stage 2 Concrete operations. Later stage.	*2.71* Ability to use non-representational symbols in plans, charts, etc. *2.72* Ability to interpret observations in terms of trends and rates of change. *2.73* Ability to use histograms and other simple graphical forms for communicating data. *2.74* Ability to construct models as a means of recording observations.	*2.81* Awareness of sequences of change in natural phenomena. *2.82* Awareness of structure-function relationship in parts of living things. *2.83* Appreciation of interdependence among living things. *2.84* Awareness of the impact of man's activities on other living things. *2.85* Awareness of the changes in the physical environment brought about by man's activity. *2.86* Appreciation of the relationships of parts and wholes.
Stage 3 Transition to stage of abstract thinking.	*3.71* Ability to select the graphical form most appropriate to the information being recorded. *3.72* Ability to use three-dimensional models or graphs for recording results. *3.73* Ability to deduce information from graphs: from gradient, area, intercept. *3.74* Ability to use analogies to explain scientific ideas and theories.	*3.81* Recognition that the ratio of volume to surface area is significant. *3.82* Appreciation of the scale of the universe. *3.83* Understanding of the nature and significance of changes in living and non-living things. *3.84* Recognition that energy has many forms and is conserved when it is changed from one form to another. *3.85* Recognition of man's impact on living things—conservation, change, control. *3.86* Appreciation of the social implications of man's changing use of materials, historical and contemporary. *3.87* Appreciation of the social implications of research in science. *3.88* Appreciation of the role of science in the changing pattern of provision for human needs.

Interpreting findings critically

.90

1.91 Awareness that the apparent size, shape and relationships of things depend on the position of the observer.

1.92 Appreciation that properties of materials influence their use.

2.91 Appreciation of adaptation to environment.
2.92 Appreciation of how the form and structure of materials relate to their function and properties.
2.93 Awareness that many factors need to be considered when choosing a material for a particular use.
2.94 Recognition of the role of chance in making measurements and experiments.

3.91 Ability to draw from observations conclusions that are unbiased by preconception.
3.92 Willingness to accept factual evidence despite preceptual contradictions.
3.93 Awareness that the degree of accuracy of measurements has to be taken into account when results are interpreted.
3.94 Awareness that unstated assumptions can affect conclusions drawn from argument or experimental results.
3.95 Appreciation of the need to integrate findings into a simplifying generalisation.
3.96 Willingness to check that conclusions are consistent with further evidence.

These Stages we have chosen conform to modern ideas about children's learning. They conveniently describe for us the mental development of children between the ages of five and thirteen years, but it must be remembered that ALTHOUGH CHILDREN GO THROUGH THESE STAGES IN THE SAME ORDER THEY DO NOT GO THROUGH THEM AT THE SAME RATES.
SOME children achieve the later Stages at an early age.
SOME loiter in the early Stages for quite a time.
SOME never have the mental ability to develop to the later Stages.
ALL appear to be ragged in their movement from one Stage to another.
Our Stages, then, are not tied to chronological age, so in any one class of children there will be, almost certainly, some children at differing Stages of mental development.

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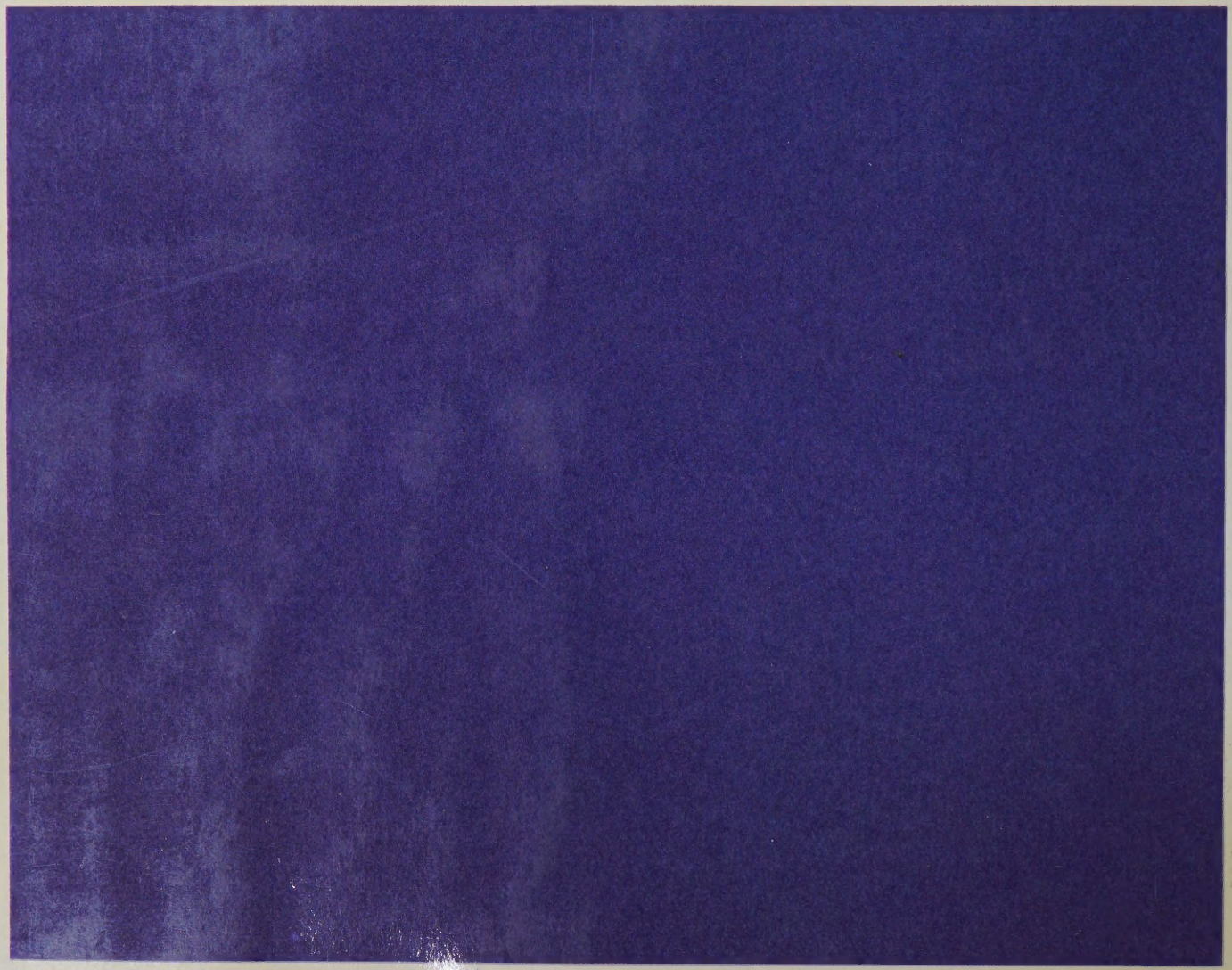

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